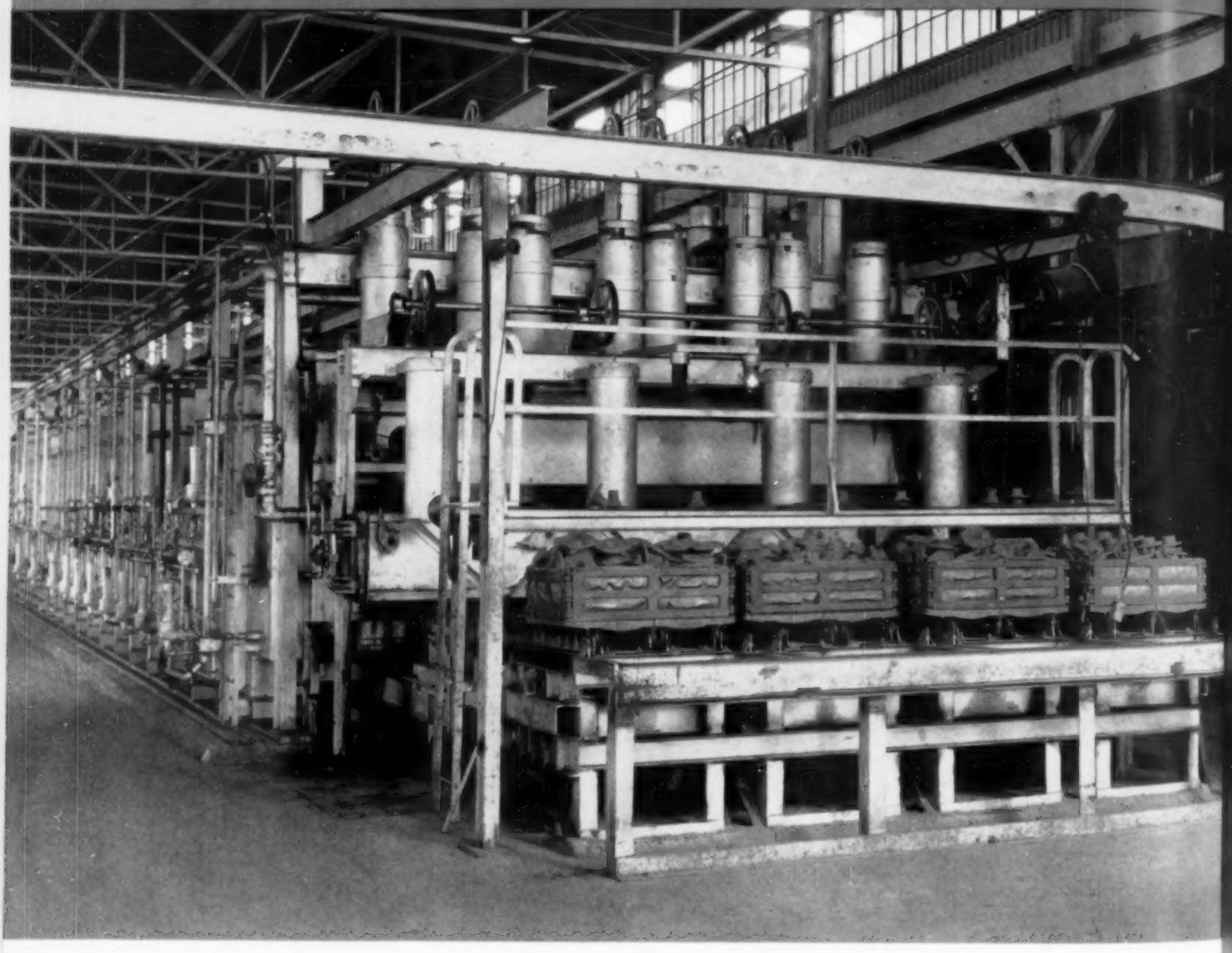
METAL PROGRESS

May, 1938

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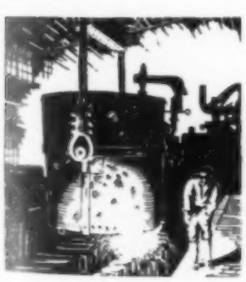
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METAL PROGRESS

Vol. 33 *May, 1938* *No. 5*

The Lamellar Family

A Note by Professor Sauveur

THERE ARE THREE SISTERS in the Lamellar family, called respectively Troostite, Sorbite, and Pearlite. At least these names had been given to them when their existence was discovered, and had been ratified by a baptismal conclave duly assembled for that purpose. They were adopted by all interested in that family and universally used until quite recently, when some writers suggested that the three sisters, although not by any means identical triplets, should be called Pearlite, because of the tendency exhibited by Troostite and Sorbite to imitate a certain characteristic of their sister Pearlite. That characteristic, however, to which the sisters owe their family name "Lamellar," while fully developed in Pearlite, is little more than latent in Troostite, and remains sketchy in Sorbite. Pearlite, moreover, always has the complexion of a full-blown rose because of the sufficiency and constancy of the iron running through her veins, whereas sisters Troostite and Sorbite may at times be anemic because of a lack of iron, or florid because of too great an abundance of it. Aware of this condition, our reformers would refer to Sorbite and Troostite as "Fine Pearlite" or "Very Fine Pearlite," which reminds us of the little bear, the middle-sized bear, and the big bear.

It is difficult to conceive of a single reason by which such change in our nomenclature could be justified. It certainly would make for confusion.

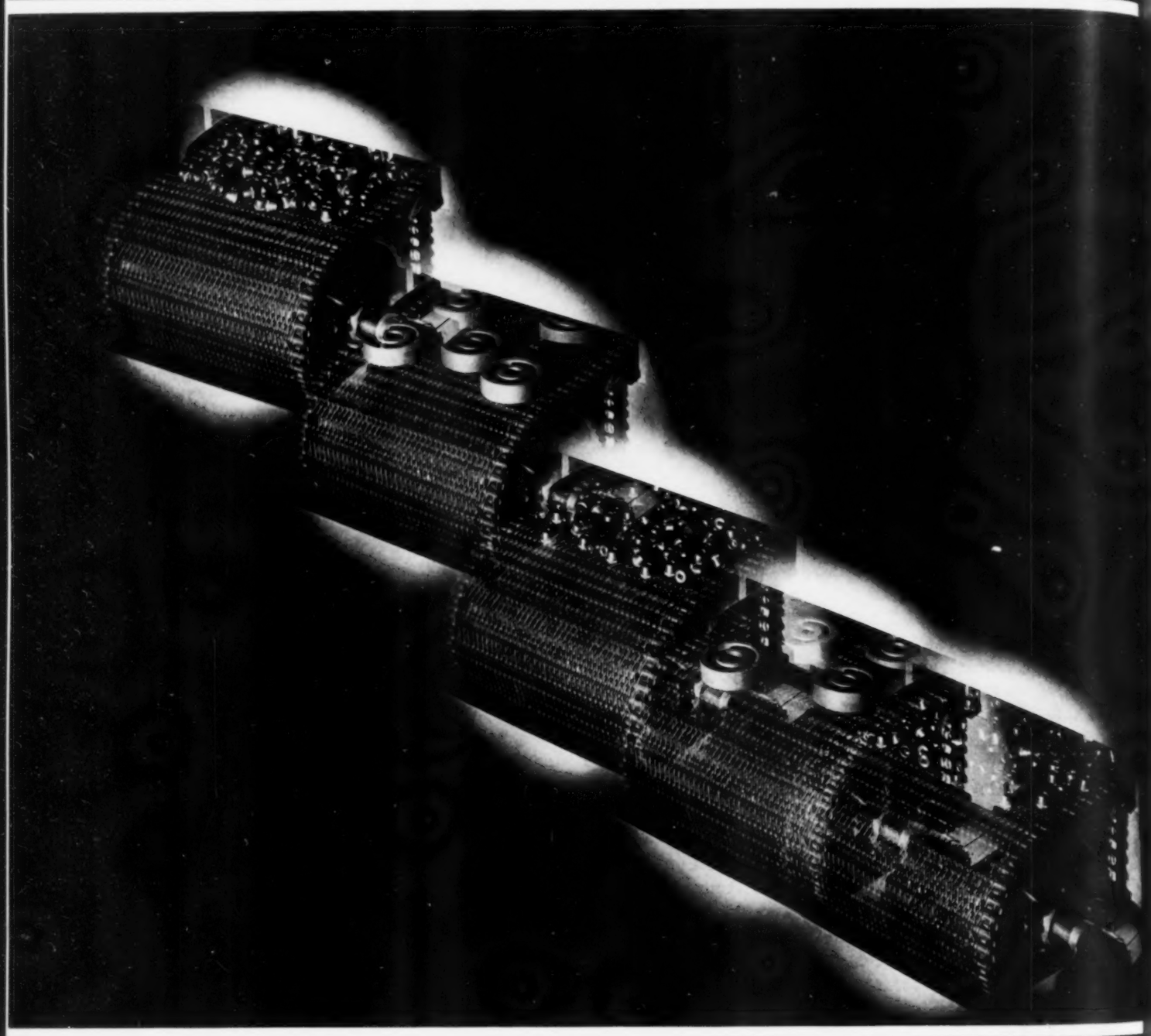
In the opinion of the writer, the matter should be referred to a Committee on Nomenclature, and if it acts wisely, it should oppose these new designations and should recommend that their family name be added to the Troostite and Sorbite with which we are now concerned, and that they should be known as Lamellar Troostite and Lamellar Sorbite, thereby distinguishing them from some cousins several times removed and called likewise Sorbite and Troostite, but who belong to the Granular family. These cousins should be referred to as Granular Troostite and Granular Sorbite. In this fashion there would be no excuse for attributing to the members of one family the vices or the virtues belonging by right to the members of the other.

ALBERT SAUVEUR

Editor's Note: Persuasion is only matched by the charm of this communication from the *doyen* of American metallurgists. At the risk of breaking the spell, it should be mentioned that the case for a revised nomenclature has been argued in *Transactions* in March 1936 (vol. 24, p. 225) and in several articles in Metal Progress for August 1935.

Briefly, it rests on the evidence of microscopic studies at high magnification and resolving power. Austenite apparently transforms into a laminated structure at any cooling rate slower than that required to produce the acicular structure martensite even momentarily. On the other hand martensite, on being tempered, does not change into a laminated structure; the precipitated carbide collects in fine globules.

Even though there may be an unlimited range of fineness to coarseness for each structure, the lamellar and globular aggregates are fundamentally unlike. The proposal to which Professor Sauveur objects, therefore, is to call "pearlite" all the lamellar microstructures resulting from the direct transformation of austenite at Ar_1 or Ar′, and to call "sorbite" all the globular structures resulting from the further decomposition of martensite.



Even when steel parts are hardened from a conveyor type of hardening furnace, considerations such as economy and flexibility of operation warrant the installation of batch furnaces for tempering, except where a uniform flow of work for subsequent processing is required

Factors in the Selection of Tempering Furnaces

MANY OF US who work with metals, heat treat them, and buy furnaces for heat treatment, quite casually accept the idea that where we install a continuous hardening furnace our tempering furnace must likewise be continuous. While in some cases (later to be defined) the use of continuous tempering equipment is thoroughly justified, the decision between continuous or batch furnace is strictly a matter of analysis; after selecting a continuous *hardening* furnace, the engineer should carefully set aside the conclusions he has arrived at in connection with his hardening equipment, and apply a somewhat different set of considerations in the selection of tempering furnaces. Overlooked, in many instances, are the sharp differences between the hardening and the tempering operations. It is the purpose of this article to bring these differences to light, and particularly to show how they influence the selection of the correct type of tempering furnace.

Tempering Contrasted With Hardening

Consider the essential differences between hardening and tempering. Foremost of course is temperature. Hardening necessarily means heating work through the critical point, followed by a quench. Tempering, on the other hand, rarely exceeds 1250° F. Therefore we encounter two distinct temperature ranges and, as it so happens, two vastly different heating methods.

In heating steel for hardening, most of the heat is transferred by radiation. Because radiant heat travels in straight lines and is absorbed, or reflected, by any body in a path between its source and the object being heated, hardening furnaces are carefully loaded so as to insure uniform heating. Equally important is the prevention of warpage caused by uneven heating. Correct hardening furnace design, therefore, presupposes two vital factors:

1. A source of uniform radiant heat.
2. Ample hearth area.

Tempering furnaces, on the other hand, are most efficiently heated by convection. This distinction is important for it means that, regardless of the shape of the parts to be tempered or the density of the load, the heat can be "blown" over the metal surfaces so as to bring the parts to the correct temperature. Whereas correct hardening practice depends on radiation and hearth area, *tempering* relies on convection, uses a minimum of hearth space, and can be carried out on work piled up, rather than spread out.

By Leroy A. Lindberg
Vice-President, Lindberg Engineering Co.
Chicago

In connection with these two distinctly opposed *methods* of heating, there is the difference in heating *time* to consider. Where it may require an hour to heat work to quench in a 1500° F. furnace, it will take approximately three to four times that long to heat it properly in a tempering furnace at 400° F., and approximately two hours to heat to temperature in a furnace at 800° F. As the temperature at which work is to be tempered increases, the heating time decreases. Based on a given production, furnaces of larger capacity will generally be needed for heating a given amount of work at low temperatures than to a high temperature in a given time.

Reduced to fundamentals, the modern convection tempering furnace is simply a closed chamber containing the charge, a source of heat and a fan, all arranged in such a manner that any air which is discharged by the fan must pass through the charge in order to return to the fan.

Because the combination of the batch type of tempering furnace for production work in connection with a continuous type of hardening furnace is sometimes misunderstood, each of the factors which influence the choice will be considered separately, as follows:

1. Quality of work
2. Maintenance
3. Floor space
4. First cost
5. Operating cost
6. Labor
7. Flexibility
8. Subsequent operations



Dense Loads, Such as Small Screws or Bolts, Are Pervious Enough to Circulated Air so That They May be Extremely Uniformly Heated by Convection Currents. View is of Leeds & Northrup Homo tempering furnace

Quality of Work — The uniformity of heating obtainable with properly designed tempering furnaces of convection type — either continuous or batch — is very satisfactory. Even where extremely dense loads are encountered, and these include such items as very small screws and bolts, through which it would seem quite impossible to force air, tests on batch type furnaces by means of multiple point pyrometers, with thermocouples placed at various sections of the load, show very uniform results.

An advantage claimed for the conveyor furnace is that the operator cannot remove the work until it has traveled completely through the furnace and presumably has had the required heating time. However, adequate controls can be installed in either type. A recording pyrometer on the batch furnace definitely indicates the heating time. If it is suspected that the operator of a continuous furnace, attempting to catch up on production, is speeding up the conveyor, the switches or variable speed control can be set by the supervisor and locked.

Maintenance — Because the continuous furnace has a great deal more moving mechanism exposed to heat than the batch type furnaces, it can be safely assumed that maintenance of the batch furnace will be considerably less than that of the continuous furnace. Ordinarily, two

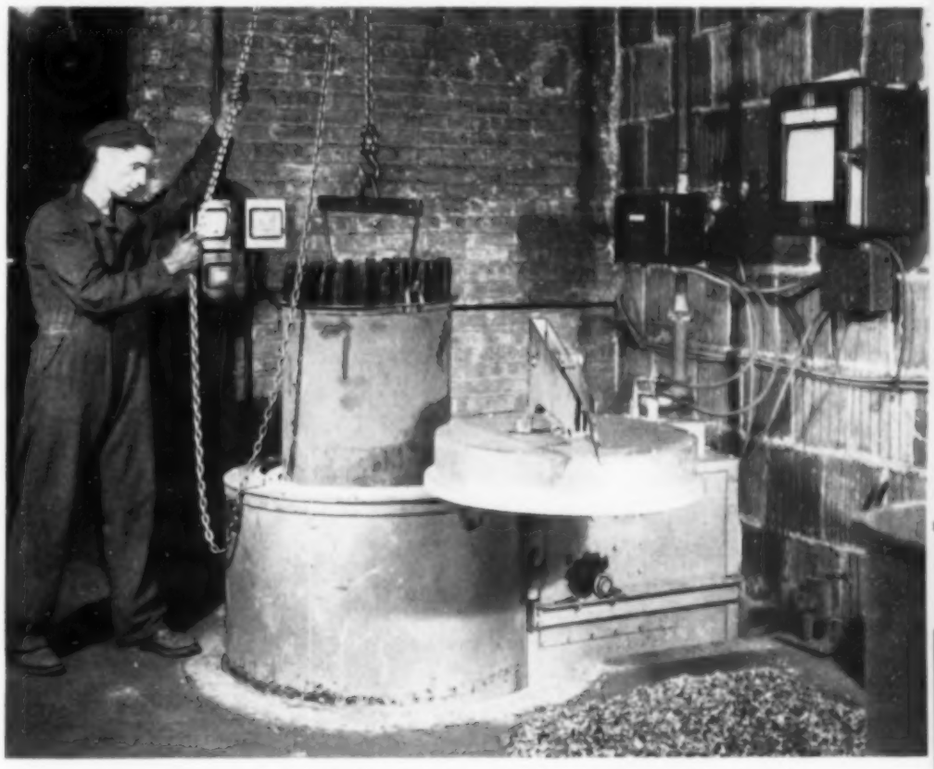
or more batch furnaces for tempering are installed on the production line — so that repairs to one furnace would not entirely cut off production, as would be the case where one continuous furnace is used.

Pile Up Rather Than Spread Out

Floor Space — Floor space is ordinarily charged to the individual department at so much per square foot per year — therefore, floor space is an important cost factor.

This point can be effectively illustrated by a simple comparison between a heat treating furnace and the stockroom of any industrial plant. In the stockroom, all parts are stored in bins, tote boxes or barrels if at all possible; that method makes for reduced floor space and reduced charges to that department. Were the parts spread out over the floor instead of compactly loaded in bins, the management would soon inquire the reason.

Since the "floor space" or hearth of a furnace is ever so much more costly, particular care should be taken so that parts to be tempered are not spread out over valuable hearth space when it is possible to load them compactly for processing. For example, if work is placed 20 in. high in a batch furnace, as compared to 2 in. high in a conveyor furnace, the hearth area is theoretically reduced to one-tenth. Ordinarily it can be assumed that the batch furnaces for tempering will occupy from 25% to 40% of the floor space required for a continuous furnace.



Parts of Considerable Weight Are Also Economically Heated by Convection in Currents of Air Properly Heated in an Adjoining Chamber. View is of Lindberg Cyclone gas fired furnace

First Cost of batch type furnaces of capacity equal to a continuous furnace for tempering varies between one third and one half that of the continuous type. In addition the installation of a continuous unit is usually somewhat costlier. In cases where the batch furnaces must be placed in pits, and a self-contained continuous furnace would not require a special foundation or pit, the erection expenses would be more nearly alike.

Batch units by reason of their smaller size and standard construction ordinarily can be delivered in a few weeks time. Continuous furnaces, being almost entirely special, require considerably more time for delivery.

Operating Cost — Due to constructional differences, the operating cost of the batch furnace is generally between one half and two thirds that of a continuous one. The former has a smaller chamber per unit of output, and is completely closed when in operation. The continuous furnace has not only a much larger chamber with necessarily higher heat absorption and radiation losses, but in addition the ends are usually open. Heat absorbed and taken out by work baskets in the batch units is usually considerably less than that absorbed by the conveyor belt of a continuous furnace.

Labor Cost — A great many cases arise where labor saving alone seems to justify the installation of a continuous tempering furnace. Before a decision is made, however, the figures for *both* types should be carefully compared. There is a great misapprehension concerning

this one point alone, primarily because the word "continuous" seems to imply minimum labor, whereas "batch type" has (in the minds of many of us) become a symbol of constant attention and higher labor costs.

Unless the continuous tempering furnace is automatically loaded (for instance, a conveyor from the quench tank) it requires the constant attention of one man. At the very least it requires labor for removing the work after it has gone through the tempering furnace and dropped into tote boxes or containers. It is desirable for one man to be on hand for prompt action if parts jam or tangle on the conveyor belt or in the mechanism.

Assume that we use a continuous hardening furnace in connection with batch type furnaces for tempering and that a flight conveyor is installed in the quench tank, and that we arrange the conveyor so that it discharges into containers or baskets for the batch furnaces. The labor required would resolve into the following steps for each load:

1. Remove basket of tempered parts from batch furnace.

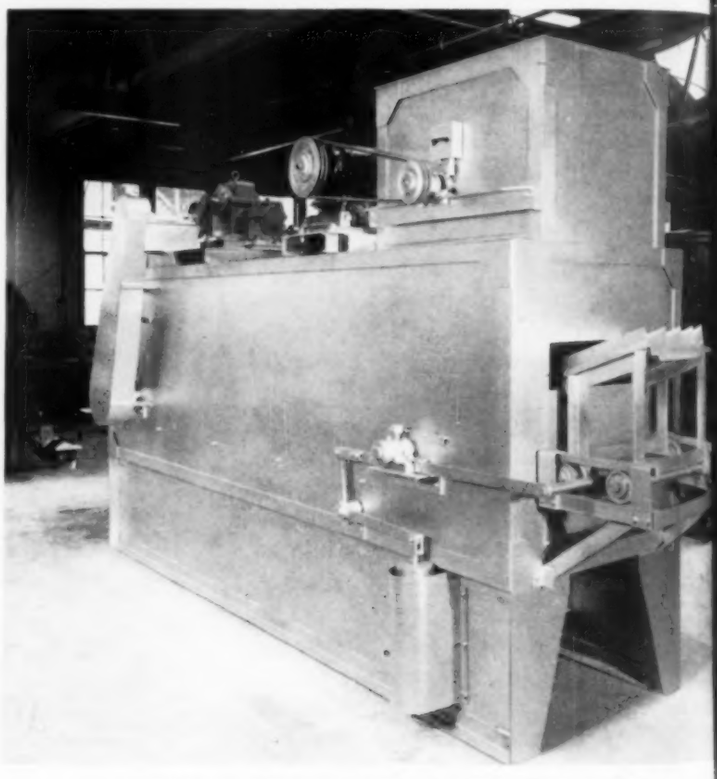
2. Remove loaded basket from quench conveyor discharge and place it in batch furnace.

3. Replace empty container at conveyor discharge at quench tank.

Experience shows that the above operations can be readily accomplished in approximately five minutes, using a hoist suspended from a monorail. Assuming the use of two furnaces and a two-hour heating time, batch furnace labor would amount to five minutes per hour. For the balance of the hour the operator is free to do other work without any further supervision of the process. Additional floor space, higher original cost, operating cost, and extra maintenance cost are high prices to pay for such small labor saving — especially since this "saving" is made only if no labor whatever is charged to the continuous furnace.

Flexibility — In laying out our heat treating department, we attempt to select equipment which provides a maximum amount of operating flexibility. Our goal is to operate furnaces at somewhere near the maximum attainable efficiency. This requires, in the case of a continuous tempering furnace, a steady flow of work throughout the week without too frequent changes of temperature. When temperatures vary appreciably, or production slackens to any great degree, costs are far higher than they should be.

In the comparative case of two batch furnaces, we can operate at two different temperatures simultaneously. We can change temperatures quickly if need be. We can even shut one unit down completely if production is slack. And where breakdown of the continuous furnace means a halt in production, breakdown of one of the batch units leaves the other still operating.



Continuous Furnace for Heating Motor Rotors Prior to a Brazing Operation. Throughput can be regulated to keep step with subsequent operations on an assembly line

Subsequent Operations — There are a number of processes requiring the installation of continuous tempering equipment where the use of batch type furnaces would be inconvenient, costly, or totally unsatisfactory. First,

and this is perhaps the widest application for continuous units, is in those processes where work must be delivered hot so that further operations can be done before it cools. The last furnace pictured is a continuous unit which preheats rotors prior to a brazing operation. Not only must the rotors be preheated, but they must also come from the furnace at a rate slow enough to enable the man handling the brazing operation to do a satisfactory job.

Closely allied to this are "sweating" operations, where the heat carried out in the work is definitely needed to complete the operation. In such cases, continuous furnaces are a practical method of securing a flow of work just sufficient to keep up with subsequent steps. Another application of this type is in spring plants, where leaf springs are "fitted" immediately after the tempering operation. Workmen manually adjust the curve of the leaf to a templet so that the set of springs nests properly.

In some instances fairly heavy parts such as crankshafts are carried on a monorail conveyor to the next department. In this case pieces are removed one by one from the furnace conveyor and immediately transferred to the monorail hooks or carrying devices. Such a continuous tempering furnace can be timed to feed parts in accordance with the speed of the monorail conveyor.

Thus it is evident that continuous furnaces are practical where subsequent processing depends on a given flow from the furnace, a definite temperature of work for further operations, or where work is being carried to other departments by overhead conveyor.

Plainly, the factor of what is to be done with the parts after they are tempered is really the most important criterion as to whether a conveyor tempering furnace is required or not. When parts need not be handled in any of the ways described above, then the batch furnace is a logical selection, for its uniformity is equal to that of the continuous draw furnace, it is lower in first cost, requires less floor space, operates on less fuel or power, and provides a greater degree of flexibility. Many large plants in the automotive and farm equipment industry, where continuous operation is generally favored, have recently installed batteries of batch furnaces for the tempering of hardened parts — proof that the above considerations have not been overlooked where careful and experienced engineering seeks quality and operating efficiency.

Bimetallic Compounds and "Order-Disorder"

By Cecil H. Desch

Extracts from Presidential Address ("A Chemist's View of Metallurgy") British Institute of Metals, March 8, 1938. Preprint No. 799

IN METALLOGRAPHIC WRITINGS of 25 years ago or earlier, a prominent place was occupied by intermetallic compounds. That alloys often differed so greatly in properties from their components was put down to the formation of definite compounds, which were identified in various ways — by singular points on property-composition curves, by direct separation of crystals from the melt, or by analysis of residues. In 1914 the formulas of 263 such compounds were known with more or less certainty, while it was considered that many more must exist from other evidence such as breaks in the e.m.f. curves at certain atomic compositions, or even from marked changes in color.

These compounds puzzled chemists for two reasons: Such formulas as $NaHg_2$, $AlAu_2$ and $AuSn_4$ disregarded all the rules of valency, and many of them had the remarkable property of taking an excess of one or both of their component metals into solid solution while retaining their homogeneous structure and principal properties. It was therefore clear that they differed in constitution on the one hand from salts and on the other from organic compounds, from a consideration of which the doctrine of valency had arisen. A "metallic" linking had to be assumed, differing from both the ionic and the homopolar linkings already familiar to the chemist.

The second difficulty was of another kind. The existence of a homogeneous phase extending over a *range* of composition, but including a simple atomic ratio, was foreign to chemical ideas. When Berthollet, in 1832, called into question the law of constant proportions, a long controversy was started. John Dalton said, 134 years ago, that the quantitative laws of combination of elements were such as would hold *if* each element were made up of similar atoms, and certain ratios existed between their weights. On that simple foundation the whole

(Continued on page 514)

Aside from the construction of highly engineered fuselage, wings and control surfaces, an aircraft factory is largely an assembly plant for an almost unlimited number of instruments and interior fittings

Aircraft Construction in Southern California

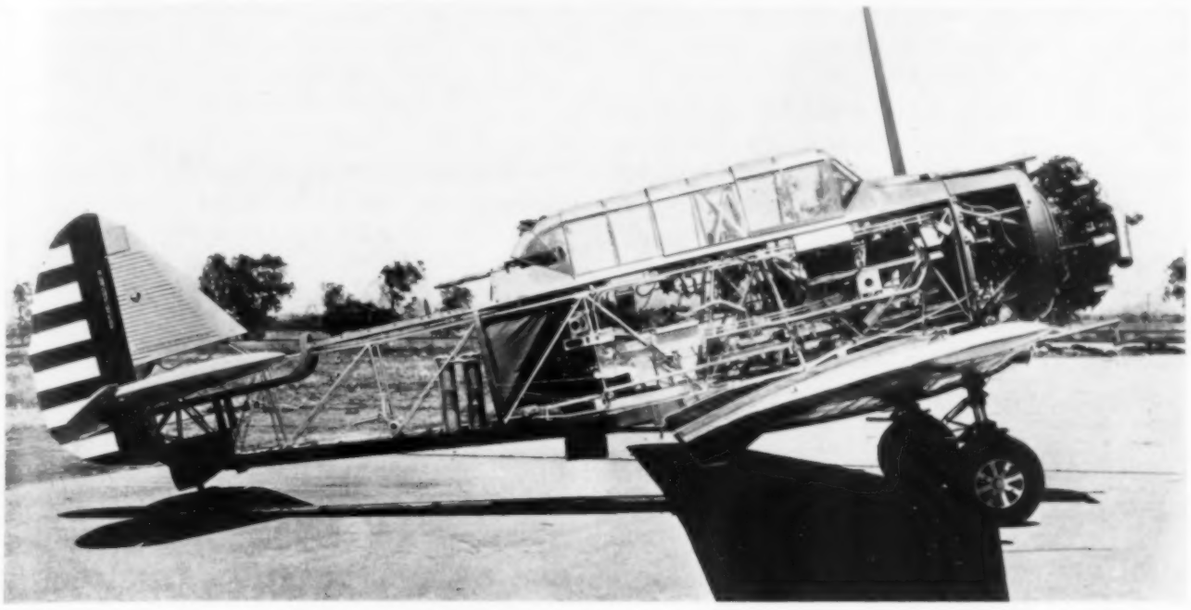
SINCE AIRCRAFT construction is one of the principal industries of Southern California, the technical programs of the cooperating societies at the recent Western Metal Congress devoted much time to its manufacturing problems. Opportunity was also given for visiting the plants — which fortunately are in full production, although largely on craft for the army and navy. Foreign transport companies also seem to have money for new equipment. It was said that factories abroad are so occupied with rearmament and pre-occupied with the matter of speed rather than safety, that they now have little time or attention for commercial aircraft. To an inexpert eye, however, the 20-passenger transport seems so close in size and design to the army bomber that it might readily be converted.

Aircraft is an industry of young men — not surprising in view of its age and its unconventional aspects. Probably few but adventurous youngsters (certainly no conservative oldsters) would train themselves and plan on devoting the remainder of their lives either to the design, construction, or operation of aircraft. This is strikingly true of the workmen who swarm about a California factory. Ninety per cent of them are in their twenties. Young mechanics are probably the easiest to teach the new operations of welding steel, riveting duralumin, fitting and assembling the thousand-and-one items that go into a completed ship, most of them invented since 1920.

One gets the idea that an aircraft factory is a huge assembly plant. Press department, machine shop, welding department, all occupy minor space (and time) compared with the erection of the fuselage and wings. This, in turn, is only one third the job. Then comes the installation of control instruments and the interior finish and equipment, either for peaceful or warlike purposes, and this is an even bigger job than the fuselage construction. Lastly are the engines and propellers — very expensive units made elsewhere and arriving complete, each in a heavy shipping box.

Even though mass production conveyors common in factories making small electric motors, refrigerators or farm equipment are still lacking, a certain degree of standardization is already apparent. In pursuit ships, for instance, arrangements are made so that a slightly damaged wing or tail can be readily removed entire, and a duplicate quickly attached. Sides and top coverings of fuselage are bolted on in large panels, removable so interior fittings can be readjusted or repaired by workmen from the outside, where there is some elbow room. The structure of large transports is similarly sectionalized. An engine is independently mounted on its own frame and this in turn is attached to the nacelle with perhaps four bolts; all elec-

Informal Observations
by the Editor



Two-Seater Training Plane Made by North American Aviation for U.S. Army. Note (a) side covering removed as complete panels, laying bare (b) great number of interior fittings and controls; (c) sectionalized skeleton of welded steel tubing

trical and most other connections are of the socket type so that the power plant can be "plugged out" and "plugged in" in 14 min. — a record, or something. These connector details are illustrated on page 358, April issue.

With all the above allowances the general impression is that an enormous amount of labor is expended in building up somewhat complicated sub-assemblies from a multitude of pieces, some of them small enough to be reminiscent of Meccano, the toy. Some of this is eliminated by pressing dished and stiffened units from a single large plate, as is described later.

Small assemblies or more complex units made of steel or aluminum forgings, aluminum or magnesium castings (either sand cast or die cast) are being more widely utilized as the producers thereof get to appreciate the special demands of the aircraft industry. Their use may save considerable erector's time; it was said, however, that these items create a second bottleneck, this time in the machine shops. A forging, for instance, may require as many as a dozen precise machine operations before it is ready for assembly, and this work so far is largely done on contract in small outside shops. General consensus was that the recent improvement of magnesium alloy castings, particularly die castings, was an outstanding event. (Arthur W. Winston, metallurgist for Dow Chemical Co., read a paper on this matter before one of the ✪ sessions of the Western Metal Congress.)

The metals used by the aircraft industry (other than for engines and instruments) were described by J. Richard Goldstein in an ✪ paper printed in METAL PROGRESS last month. For small aircraft — say two-seaters — the fuselage skeleton is designed to carry the stresses, and is welded up in thin-walled chromium-molybdenum steel tubing. This work is adequately systematized. Individual pieces are machine-cut to length in templates having the proper shapes at the end so they fit into complicated intersections very neatly. Jigs hold the pieces in correct position during welding, the set-up swiveling about so the blowpipe and rod can be held in a convenient posture. Completed skeletons are not heat treated, the mild air-hardening qualities of the alloy being relied upon to give joints about equal in strength to the original tubing beyond the heat affected area. Certain highly stressed parts of engine mounts and landing gear are welded up of the same material (either tubing or bent sheet, S.A.E. X-4130) and heat treated to restore strength and toughness.

Adequate training, excellent equipment, close supervision and painstaking inspection are relied upon to give satisfactory joints. Experi-

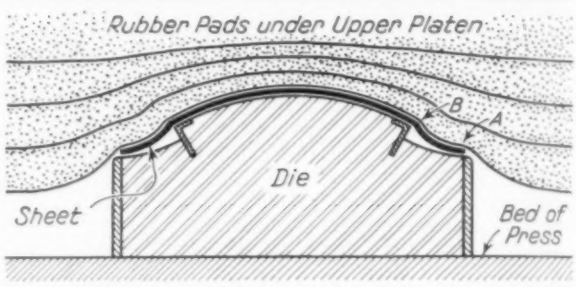
ence shows the sufficiency of these precautions. F. C. Fantz, vice-president of Midwest Piping & Supply Co., St. Louis, speaking at a meeting of the American Welding Society, testified to this belief from 15 years of experience with field welds in high pressure piping. He said that quality of joint as made either in field or shop is due as much to capabilities of the process and excellence of supplies and equipment as to skill of the operator. Once procedure is set and checked to make sure that it can produce welds with the desired physical properties, it is then only necessary to train the welder in the prescribed routine. When the welder has repeatedly proved his ability to carry out the procedure, and is properly supervised to make certain that no essential is slighted, the result will be satisfactory and pass all reasonable tests.

Oxy-acetylene welding is also used in the construction of fuel tanks of sheet aluminum, both for seam welding and for covering the heads of all rivets extending through the outer shell. Tanks are carefully tested under pressure; the slightest gas leak, even into a ventilated compartment, would be a grave hazard.

In the larger aircraft the monocoque or stressed-skin construction is favored for fuselage and wings; strong aluminum alloy is the standard material. Many convenient extruded shapes are available, but the alclad sheet is the starting point for many sub-members of trusses and ribs. Larger units of odd shape required in small numbers are cut out in this manner: A pile of perhaps a dozen sheets are clamped to a template, and the shape roughed out on a band saw, trimmed by hand with a vertical milling cutter, and the necessary holes drilled.

Forming, dishing and otherwise producing surfaces of thin alclad sheet curved in three dimensions is done in at least three ways, ranging from very primitive to uniquely modern. First is a tedious hammering or rollering by hand until the dish fits over a wooden model. Next is the use of a rope drop hammer. Mating dies are cast in zinc or other fusible alloy (cast directly on wood or plaster of paris models) and fixed to anvil and ram of the hammer. When everything is ready a sheet of metal is placed on the lower die, a stack of hardwood plyboards inserted, and then removed consecutively so the upper die on each of its blows will increase the depression in the sheet by about $\frac{1}{16}$ in. Eventually the piece is formed.

The modern method was described in a paper before the American Society of Mechanical Engineers by Henry E. Guerin, of Douglas Aircraft Co. It consists of a single forming die made of metal, placed loosely on the horizontal bed of a powerful hydraulic press. Under the upper bed is a pile of live rubber mats or blankets, which, when pressed down on the die, elastically assumes the form of an upper die and squeezes the flat plate to the required shape. This eliminates the need of upper dies for each of the 9500 shapes in use at the Douglas plant. It also removes half the possibilities of scratching, as the rubber under pressure creeps along with the deforming sheet.

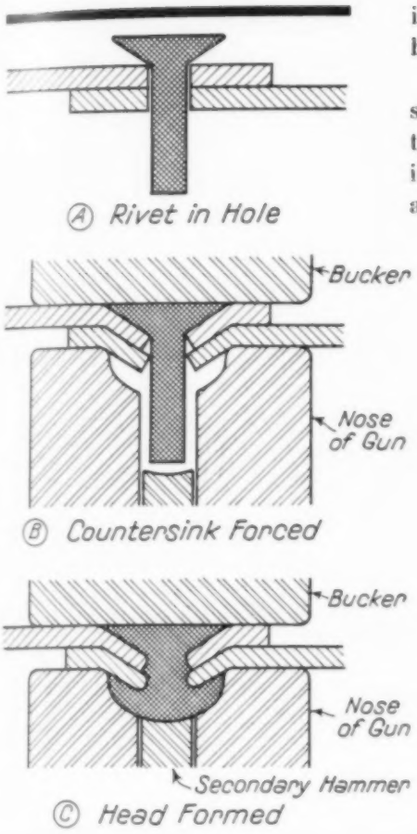


Conditions for Forming and Trimming in One Stroke, Using Elastic Rubber Mats for an Upper Die

Two presses are in use at the Douglas plant, one of 2000-ton capacity, 72-sq.ft. bed area, and 60-in. opening, and one of 5000-ton capacity, 8x15½-ft. bed, 72-in. pressure cylinder, and running speed of 250 in. per min. Obviously as many shapes can be formed at one stroke of the press as dies can conveniently be assembled on the bed.

Forming and trimming to shape can be done on a single stroke if the conditions are as shown in the sketch. The sheet must be oversized enough that the outer edges at *A* are tightly seized between die and rubber; further compression of the latter forces the taut rim down past edges *B*, which are of steel, inset in the soft metal die. Such a three-dimensional trim is fairly difficult to make with metal punches.

Probably the greatest advantage is the ability to make readily large, complicated pieces containing flanged holes, stiffening beads or dishes. In the assembly of wing ribs, for instance, large units have cut the number of individual parts by half. Weight is also reduced about 25%, principally by eliminating riveted connections which could not be relied upon to carry bending stresses.



Three Steps Needed to Drive Rivets in Aluminum Sheets With Double-Acting Gun so Exterior Surface Is Smooth

Riveting is the standard method for joining duralumin. Compared with spot welding it seems slow and laborious. Rivet heads also have the disadvantage of presenting considerable drag to the aircraft in flight. An interesting development is the countersunk rivet, forced into a flat seam by a countersinking nose on the gun, and the inside head may then be upset by an auxiliary central hammer-head. The three steps are illustrated in the sketch.

Desirable as spot welding would be, it is still restricted to non-stressed fittings and furniture. Methods were described by Charles L. Hibert, Consolidated Aircraft Corp., San Diego, Cal., before the American Welding Society.

One annoying variable that still exists is the *surface* of the sheets to be joined. Work must therefore reach the welding department disassembled, and be sandpapered or cleaned chemically of surface oxide on both top and bottom of all welded points. This is done by immersing the edges 30 sec. in a weak mixture of hydrofluoric acid with alcoholic solution of tragacanth gum. If heat oxide is present, it must first be scratched with emery paper to permit the acid to work underneath. The acid-gum is washed off in running water after which the loose oxide can be swabbed off with a wet rag.

Other variables must be controlled, notably the shape and surface of the electrodes. Mr. Hibert has fixed upon an electrode tip $\frac{5}{8}$ in. diameter, $1\frac{1}{2}$ in. long, with a 7° machined end. Copper is the best material known, although it alloys readily with the aluminum and "splashing" occurs. Hence it is absolutely necessary to clean tips with No. 7/0 sandpaper after six to ten welds, and re-dress them after 200 to 400 welds.

Clamping pressure applied to the electrodes should be constant, once fixed for the particular joint. Increase in pressure requires higher current, for it lowers contact resistance. Very quick welds ("shotwelds") are not entirely satisfactory; time of current dwell can be raised to ten cycles with general improvement in uniformity. What happens is that a small slug melts and then solidifies, the spot weld therefore being a small casting inside a wrought article, and worth only the shear strength of the alloy in its cast condition. The spot weld fails in tension along the boundary of this cast slug and the parent metal.

To adjust the welding machines, as a practical matter, it is necessary to set pressure and time and then adjust the current to obtain the best weld as shown by a tearing test. A weld that will pull a slug with a diameter four times the sheet thickness when rolled apart with pliers is considered satisfactory. As a precaution, all long seams are finished with rivets, to prevent tension failures from starting. Even at best, some spot welded aluminum parts come apart after being in service — although this now occurs much less frequently than three or four years ago — so that a ready and infallible means of inspection is still lacking.

As pointed out by Mr. Goldstein in his article last month, few structural parts of stainless steel are now going into aircraft, and one would expect considerable "sales resistance" from a shop organization asked to fabricate hard springy steel when it has been trained almost exclusively on the more plastic duralumin. From its welding characteristics, Mr. Hibert ranked 18-8 as "ideal, because of its low carbon content, high electrical resistance and oxide-free surfaces. It has a wide plastic range; consequently the weld is equivalent to an annealed, fine-grained wrought structure, and hence has good physical properties when stressed in tension, torsion or shear."

Carl de Ganahl, president of Fleetwings, Inc., Bristol, Pa., warned against any supposition that stainless can be welded without experienced labor. Watchful intelligence is necessary



Inspection of Pioneer Airship Made of Stainless Steel Shows no Corrosion After Three Years of Service and Three Years of Exposure to Industrial Atmosphere

to recognize variations that influence quality of welds, even when automatic devices on the welding machine indicate pressure and current conditions to be normal. One prime source of weak welds might be called the "proximity effect." Suppose a small reinforcing pad is to be laid on a surface; the first spot weld will be satisfactory, the second one nearby less so, and the last spot may perhaps not weld at all unless the current be continually increased to take care of that part diverted or short circuited through the spots already welded.

Messrs. de Ganahl and Sutton (who have already been contributors to METAL PROGRESS) presented a paper on "Stainless Steel for Aircraft" to the ⛑ aeronautical session, in which they described the manufacturing methods utilized for a large number of stressed-skin wings and movable surfaces for Air Corps ships requiring extreme lightness and maximum rigidity. Rapid spot welding was used for practically all joints, and the outer surfaces are exceptionally smooth, there being no rivet heads or protuberances of any kind. One type of wing was so constructed that under flight conditions it is almost free from torsional stress, since the center of applied air pressure is nearly coincident with the elastic center. In this type of wing, integral fuel tanks can be built in by merely providing baffles and tight end bulkheads. Outboard of the fuel tanks the wing can be sealed to provide flotation.

It is well known, of course, that a great deal of welded stainless has been giving excellent service in high speed railroad cars and in deck structures on steamships, so that ample experience and evidence of quality are now available for the aircraft industry. Stainless steel aircraft are also known. One was built at least six years ago by Edward G. Budd Mfg. Co., and flown steadily for three years by many pilots in America and Europe. For the last three years it has been parked in front of Franklin Institute in Philadelphia. A recent inspection showed no signs of deterioration in structural parts or welds by corrosion either from use or exposure to this industrial atmosphere.

Competitive materials are still matters of great interest to aircraft constructors, despite the near-monopoly of strong aluminum alloys. Given the proper incentive, a suitable strength-weight ratio can be developed in wood and

fabric, aluminum, stainless steel, or heat treated steel. Collateral factors indicate that wood and fabric would probably be most handily utilized in the smaller ships; aluminum seems to be pre-eminent in medium sized ones, and steel becomes more suitable in the largest ships and members where minimum commercial thicknesses can be fully utilized for carrying stress. The problem of using all these materials becomes less academic in war or rearmament times, when deliveries of any type of material are likely to be delayed or curtailed. In a war emergency, when the life of a ship in combat would be very short, the question of corrodibility would not enter, and the engineering alloy steels would be available in great quantity, but the big problem would be to develop quickly the designs, the plant and the construction art for using them. As far as could be observed, the factories in southern California are restricting themselves to welded steel frames, strong aluminum fuselages and wings, and fabric-covered control surfaces. Working in wood and fabric is almost a lost art, and steel has not yet arrived.

Pressure Die Casting

By Hans Lawetzky

Abstract from Journal of Production Engineers (Great Britain), February, 1938

IN THE PRESENT STATE of development, regarding the high compression of the metals cast, pressure die casting is intermediate between permanent mold casting and hot stamping. Consequently machines using a cylinder and piston both submerged in molten metal [as sketched on page 382 of last month's issue] are unsuitable for high pressures and higher melting point alloys. If plunger pressure is replaced by gas pressure, such a machine becomes adaptable for aluminum alloys, but is still limited to pressures below 700 psi. Higher pressures are needed to give fine-grained castings, free of air cavities and having dense surfaces so necessary for plated ware. Hence is the modern machine, wherein metal is heated separately, transferred in small quantities into a pressure chamber, wherefrom it is immediately, by action of the plunger, pressed into the die cavity.

The principle of the cold pressure chamber is based on the following idea: Immediately the molten metal enters the pressure chamber, it forms a thin skin or crust of solid metal all around which is chilled by the walls of the pressure chamber and by the access of air. This thin crust acts as a packing for the injection piston, which can therefore be given enough clearance to prevent excessive wear between the walls of the pressure chamber and the piston. The pressure chamber being relatively cold, the limit of compression is regulated only by the tensile strength of the steel used.

Aluminum alloys are cast within the range of 2800 to 4900 psi. pressure, and 1100 to 1450° F. (the upper limits for castings later to be heat treated). Corresponding figures for the strong magnesium alloys are 5600 psi. and 1150° F.

Copper-zinc alloys are cast at 6000 to 8500 psi. As is well known, temperatures are 1550 to 1650° F., at which they are in a mushy state. Other copper-base alloys which may be die cast are special bronzes or brasses with nickel, manganese and silicon; also "German silver" with a nickel content up to 9%.

Trials have been made to cast gun metal, and although the results have been favorable, this work cannot be regarded as an economical proposition due to excessive wear of the dies.

In the United States and in Russia pressure die-casting machines for gray iron casting have been developed. The Russian machine simulates the hot stamping process, the American machine employs the principle of one of the early aluminum casting machines. In both cases much experimental work has still to be done and it is not yet a commercial possibility. The American machine will deal with at least 50 lb. of metal with each shot; the Russians, on the other hand, have not succeeded in producing castings weighing more than 1 to 2 oz.

Force for moving the piston as well as clamping the dies is best supplied by a hydraulic pump, delivering into an air-loaded accumulator, this combination giving a rapid action, easily regulated as to intensity. Slight variations in quantity of metal placed in the chamber will not cause troubles in the pressure cylinder; neither will there be any elastic stretching permitting leakage along parting lines of the dies, as there would be with mechanical clamps.

An Eminent Living Metallurgist



William Reuben Webster

Our Biographical Dictionary

Metal Progress honors itself in honoring in this manner the dean of brass metallurgists, whose business and engineering ability has raised him to the general direction of one of America's largest organizations in the non-ferrous industry

William Reuben Webster

An Appreciation

"COMMITTEE X will now come to order!" was one of the cheerfullest things that could be heard at the American Society for Testing Materials meetings, long, long ago, when that society met at Asbury Park rather than Atlantic City. For "Committee X" was an informal group of kindred spirits interested in copper and brass, mills and foundries. Such men as Webster, Clamer, Price, Wolf, Cowan, Bassett, St. John, Campbell, Merica, Olson, Corse and Patch would meet at dinner and after the coffee would consider such serious things as a bigger and better American Institute of Metals and such frivolous things as a statistical and microscopical analysis of the distribution of raisins in cookies. The best conversation of the entire A.S.T.M. meeting could be had in Committee X, on any subject, professional or otherwise.

The next afternoon the first four mentioned would do Homeric battle on the golf links. As Price would tell the story at the 19th tee: "That certainly was a see-saw affair — were we ever more than one up at any time? That last putt of yours, Bill, was a heart-breaker — both of us hole high in three, but you clear at the edge of the green, and me close to the pin. And then you go and sink a 45-footer and I foozle a short one and the match! And just what did you mean: 'Good putting, my boy, is merely an evidence of strength of character'?"

By 45-ft. putts, indeed, is how his friends would measure the stature of William Reuben Webster. Beloved by all who know him intimately, he meets the definition of a successful man. Highly esteemed as a citizen of the community in which he lives, he always has been a good workman. With a scientific and analytical turn of mind, he studies each problem, taking nothing for granted until it is proven not once but more than once — his rule being that an idea should be tested three times with concordant results before it is accepted as accurate.

Born in Oyster Bay, Long Island, his parents, of old Connecticut stock, sent him to Stamford and Norwich for his schooling and to Cornell University for his mechanical engineering. Graduating in 1890, it was only three years before young Webster was superintendent of Bridgeport Copper Co., one of the American pioneers in the art of electrolytic refining of impure copper. There were many problems to be solved in those days, and the technical problems were not made any easier by the depression of 1893 — which, in its way, was a recession worthy of remembrance. It required all the ingenuity of a born Yankee to solve these problems in the light of his fundamental rule of three — three proofs to establish a fact.

Four years later, in 1897, Webster went with Bridgeport Brass Co. as foreman of its rolling mill. Last year completed 40 years of service with that concern, and now as Chairman of the Board, he sees with immense satisfaction the completion of a new, model rolling mill, adjoining his old one, incorporating all the engineering advances in furnaces and machinery that have developed in his lifetime. "W.R.", as his friends would say, had the good fortune to come to the brass industry with an engineering training and an engineering way of doing things at a time

when the industry was carried out entirely by rule-of-thumb. He had the strength of character to break down many rock-bound traditions, even then quite out-dated, and in this he had the assistance of other engineers, who early in his career he gathered about him, and who found many ways to put their theoretical training to good use in a practical way.

William Reuben Webster, therefore, represents the engineering pioneer in the brass industry, and as such the metallurgist of today delights to honor him. His ability and tenacity of purpose, thoroughness and far-sightedness have permitted him to size up new inventions and apply them in advance of most of his competitors. As an instance: His association with the Bridgeport Copper Co. was at a time when native fire-refined copper was considered the *only* suitable material for any exacting requirements. This attitude simply was not acceptable to one who knew as much as Webster did about electrolytic copper. This experience and information, practically unique in the brass industry, were put to good use in the operations of Bridgeport Brass Co., and this pioneering work on the quality of basic materials came very much to the forefront as late as the World War. Webster's experience in the evaluation of suitable raw materials for cartridge cases and other brass products was of immeasurable value in the efficient production of ample munitions. He was largely responsible for the confident use of high grade electrolytic copper and electrolytic zinc in place of the relatively scarce materials produced by direct processing from the few raw ores of sufficient purity available in this country.

Through this same far-sightedness the Bridgeport Brass Co. was the first brass mill to use electricity as the medium for brass melting. The original installation of two 30-kw. induction melting units in 1916 was a forerunner of a practical revolution in the methods of melting non-ferrous metals, as electricity has been generally adopted by practically all of the big producers. Bridgeport Brass Co. undoubtedly was the first rolling mill to test the induction melting furnace in practical mill operations.

"W.R." again pioneered the development of modern condenser tubes. His publications on this branch of the art are considered textbook reference data on reductions in working brass, stresses caused by cold rolling and the phenomenon of season cracking. The position he took many years ago on the "inert" or annealed condenser tube, and his views on the corrosion problem, have been supported by the history of his industry.

The uncanny Yankee ingenuity shown in many mechanical conversion operations which were developed under Webster's guidance for the quantity production of such commonly used articles as electric light sockets, were no small contribution to the American large-scale economical production of such parts.

He has always contributed generously in imparting the knowledge of his accomplishments to his competitors and engineering associates — his activities in technical societies therefore being outstanding.

During the War Webster was a member of the Connecticut State Council of Defense. For many years he has been a member of the American Society for Testing Materials in which he holds memberships in several important committees. As a member of the American Society of Mechanical Engineers, he is on the Advisory Committee on Non-Ferrous Alloys and Metals of the U.S. Bureau of Standards. His interest in condenser tubes is unceasing and so he retains chairmanship of a committee on Non-Ferrous Pipes and Tubes of the American Marine Standards Committee, and is past chairman of the American Society of Mechanical Engineers' Research Committee on Condenser Tubes. His engineering and club memberships are almost too many to enumerate. In all of them he more than passively accepts; he actively gives.

Aside from Mr. Webster's many industrial and engineering accomplishments, he has played no small part in the business and civic life of the community which is close to his heart. In addition to holding various posts as director or trustee in banking and commercial institutions, he is closely associated with many civic betterment projects. His deep interest in humanity took early form as one of the founders of the Charity Organization Society of Bridgeport, and he is currently president of the Bridgeport Society for Mental Hygiene, director of the Family Welfare Society and Bridgeport Young Men's Christian Association.

In addition to his many business and civic activities, Bill Webster finds time for fishing and golfing, in both of which he is ardently interested. His eager soul again shows forth in being one of the first sportsmen to go to the Rangley lakes after the ice is out in the spring. At golf he is a keen competitor and his opponents had better hedge their bets, for he never wastes a shot!

PAUL E. MCKINNEY

This continues a series of articles on toolsteels from a firm early identified with the American industry. "Historical Development of High Speed" was printed last October; "Crucible Toolsteel" last December; "Making Toolsteels in Electric Arc Furnaces" in the March issue.

Toolsteels, Past and Present

IV — Induction Furnace Melting

THE CHANNEL TYPE or "low frequency induction furnace" was developed for the melting and refining of steel and ferrous alloys, and was the outcome of the researches of de Ferranti in England, and Colby in America in the 1880's. It was further improved by Kjellin, Frick, Rodenhauser and others between 1900 and 1910. This channel type of induction furnace is essentially a single turn, step-down transformer, the secondary of which is in the form of a circular loop or ring of the metal to be melted. Its fundamental difference from an ordinary transformer on an electric power line is one of objective: In the power transformer the heat generated in the secondary is a source of loss and is reduced to the minimum, while in the induction furnace it is utilized to the maximum to melt the metal. In this respect the induction furnace may be regarded as a combination of an air-cooled transformer and a direct resistance furnace. A 4000-lb. furnace is shown in the view on the next page.

Classification of induction furnaces into "high frequency" and "low frequency" has long been used, but it is misleading and incorrect. Early furnaces possessed a bath in the form of a horizontal ring, which in certain cases necessitated the use of frequencies as low as five cycles, while small coreless induction furnaces are now operated with oscillatory currents having periodicities in the region of thousands of cycles. Since normal industrial power is generated at 60 cycles per sec. (sometimes 25), it has been convenient to designate the channel type of furnaces as "low frequency" in contradistinction to coreless induction furnaces which normally work with considerably higher frequencies.

Although a few of these early furnaces are still in use, the majority have been abandoned due to inherent metallurgical and electrical weaknesses. Metallurgically this type of furnace has definite limitations, being now confined to plain melting of certain alloys of high resistivity, such as nickel-iron, nickel-chromium, and stainless steel. The furnace must be started with a quantity of molten metal or with a specially cast starting ring of the metal to be melted. Difficulties are experienced when changing from one composition to another, on account of the necessity of leaving metal in the furnace to form the secondary circuit. This is a serious drawback in the melting of alloy steels, as its weight cannot be determined with sufficient accuracy when figuring analysis to a close specification. A further drawback is that the volume of metal contained in the channel is small in relation to the size of the furnace and the volume of refractory material; this obviously makes for low

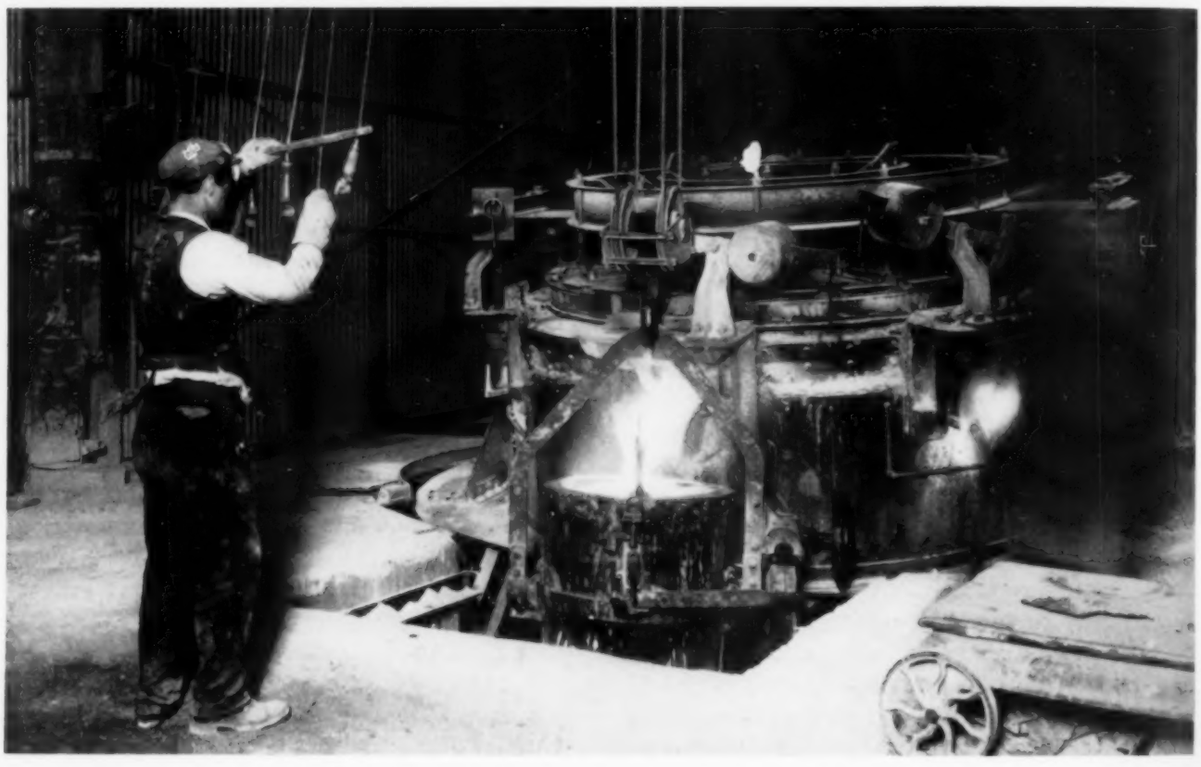
By H. C. Bigge
Supt. Toolsteel Dept.
Bethlehem Steel Co.

thermal efficiency. The area of metal surface exposed is relatively large, and as no heat is induced in the slag, the latter is not sufficiently fluid for effective refining.

Coreless Induction Furnace

The coreless induction furnace represents one of the most important contributions to the production of complex alloys and high grade alloy steels. Credit for its original development to the production of special materials of exceptional purity, and to laboratory researches.

Later it was found that the high periodicities (10,000 to 20,000 cycles) which characterized these small units were neither necessary nor desirable for larger industrial furnaces. With the cooperation of the large manufacturers of rotating machinery, motor-generator sets were successfully designed to produce current with frequencies between 500 and 2500 cycles, for energizing industrial furnaces with capacities



Induction Furnace of Channel Type, Known as a "Low Frequency Furnace," Pouring 4000 Lb. of High Alloy Steel

and for many of the subsequent refinements goes to Prof. E. F. Northrup, who carried out his researches at Princeton University in 1916 and 1917. A brief account of this may be found in METAL PROGRESS for January 1936, page 59.

Early furnaces were operated with high frequency oscillatory current supplied by a static converter like the Tesla spark gap. While the kilowatt input was restricted, it was possible to melt small charges of alloys with high melting point with unprecedented rapidity. At first these furnaces were confined to the melting of precious metals and alloys in small quantities, exceeding 60 kw. This development, which started in 1925, marked the beginning of the industrial expansion of this type of furnace.

The distinguishing feature of this type of furnace, as contrasted with induction furnaces employing closed channels, is that the bath is contained in a crucible of familiar shape. There is no need for leaving some molten metal behind, to start the next charge, and induction melting is thus rendered suitable for operations where mixtures must be changed frequently.

A furnace installation consists of a high frequency generator, condensers, a tilting furnace

of suitable size, and the necessary control instruments, regulators and switches. The furnace itself is of remarkably simple construction; no great mechanical strength is required, as the crucible is always well supported by the packing of fused magnesia and does not have to be withdrawn for pouring. Usually the furnace body, with its built-in inductor coil, is fixed in a cradle arranged for nose tilting by means of an electric crane or motor; there is therefore little movement of the crucible spout during tapping. The furnace body itself is easily replaced.

As is doubtless well known, the furnace consists essentially of a receptacle for holding the charge, surrounded by a water-cooled coil of copper tubing through which the current is passed. This generates an intense alternating magnetic field inside the coil which is sufficient to cause induced, eddy or Foucault currents of large volume in the metal contained in the furnace, and these currents heat and melt the charge. (In melting charges consisting of magnetic materials, an additional heating effect results from hysteresis.) On the inside of the coil is wrapped a mica or asbestos sheet, or a cylindrical sleeve of fused silica approximately ¼ in. thick is placed next to the inductor, and the space between the sleeve and the crucible is packed with special magnesia. This serves as a thermal insulator; in case of crucible failure it also prevents molten metal from coming in contact with the silica sleeve and the inductor coil. Asbestos tape or strips of mica, or both, insulate the turns of the copper inductor from each other. Finally, the coil is coated with an impervious, non-hygroscopic cement to prevent corrosion or short circuiting by moisture from the refractories or from the atmosphere.

Pouring a Heat From a 1200-Lb. Induction Furnace. Battery of such furnaces at Bethlehem plant contains two of 1200-lb. and two of 600-lb. capacity



Comparison With Crucible Furnace

Due to the method of heating and the small slag volume required, the coreless induction furnace has a metallurgy of its own. It is not possible to adopt, without alterations, the practice used in the electric arc furnace or the fuel-fired crucible furnace. The metallurgical processes of the fuel-fired crucible furnace are well understood, and have been described in the second article in this series (December 1937). A comparison between this furnace and the coreless induction furnace will therefore be an aid to the understanding of the latter, which is essentially an electrically heated crucible furnace.

A most important difference between the two processes lies in the crucible material. The crucibles used in the fuel-fired furnaces were made of a mixture of graphite and clay with approximately 50% carbon and 30 to 35% SiO_2. To prevent carbon contamination the crucible was made with an inner lining approximately ⅛ in. thick, analyzing about 85% SiO_2; this type of lined crucible was used for melting high speed steels and low carbon alloy steels. No clay lining was used in making carbon steels, however, and in calculating the charge allowance had to be made for the carbon pick-up from the crucible. The coreless induction furnace, on the other hand, uses a magnesite crucible for high speed steels, cobalt

Metal Balance for Heat of High Speed

	Percentage Analysis		Weights Involved		Yield Per Cent
	Mix	Ingot	Mix	Ingot	
Carbon	0.796	0.729	19.11	17.19	89.9
Manganese	0.351	0.28	8.44	6.66	78.2
Phosphorus	0.021	0.021	0.508	0.495	97.4
Sulphur	0.0276	0.025	0.662	0.589	89.0
Silicon	0.347	0.240	8.35	5.66	67.8
Nickel	0.040	0.040	0.96	0.94	98.2
Chromium	4.10	4.05	98.63	95.50	96.8
Tungsten	18.50	18.66	444.28	440.00	99.0
Vanadium	1.24	1.20	29.85	28.30	94.8
Iron			1789.21	1762.73	98.5
Total			2400.0	2358.00	98.2

magnet steels and corrosion resisting steels; a representative analysis is 82.50% MgO, 10.00% SiO_2, 1.00% Fe_2O_3, 3.50% Al_2O_3 and 2.70% CaO. Acid linings made of silica sand mixed with special binders rammed into shape over special forms are sometimes employed abroad in induction furnaces for making toolsteel.

The electrodynamic movement of the bath in the induction furnace is another point of difference between the two processes. Extensive investigations have revealed that, if the possibilities offered by the induction furnace are properly utilized, the turbulence of the bath merely accelerates the reactions with the slag and quickly eliminates any difference in composition within the bath itself. This movement of the bath presents no danger of slag inclusions in the resulting steel.

In the fuel-fired crucible furnace the slag is heated uniformly with the charge; in the induction furnace, on the other hand, the slag, an electrical non-conductor compared to the metal, is heated indirectly. It has been definitely established that, even though the top layer of the slag may be cold, this is no serious disadvantage as enough slag is kept sufficiently fluid to facilitate the chemical reactions. To obtain a completely fluid slag it is only necessary to add pulverized ferrosilicon or silicon-zirconium, and agitate the bath for a short time with a poker immediately prior to pouring.

Slags of various compositions are used, depending naturally on the type of steel melted. Analyses of typical raw materials used in coreless induction melting are given in the data sheet, page 497. As all steel melted in the coreless induction furnace is made from uniform materials of known analyses, it is not necessary to discontinue or interrupt a melt to make preliminary tests, once a standard practice has been established. Slag treatment and deoxidation program also depend upon the composition of the steel being made.

One or more furnaces are poured in a thoroughly preheated ladle, temperature readings being taken in the crucible and as the metal enters the ladle. Metal is held in the ladle until the proper teeming temperature has been attained. During this holding period the slag rises to the top of the ladle. Finally the metal is teemed or poured into small ingot molds ranging in size from 4½ to 13 in. square, inside.

It will doubtless be interesting to show a balance sheet of the metallic elements used in a heat of 18-4-1 high speed steel. The materials charged were as follows:

600.0 lb. 18-4-1 high speed steel scrap
600.0 lb. special tungsten steel remelt ingots
318.0 lb. ferrotungsten
601.4 lb. charcoal iron
108.0 lb. low phosphorus pig iron
107.6 lb. high carbon ferrochrome
58.4 lb. low carbon ferrovanadium
4.6 lb. low carbon ferromanganese
2.0 lb. 50% ferrosilicon

2400.0 lb. total metallic charge

Analyses of the metallic materials are all

Ingot Dimensions and Weights

Nominal Size	Mean Area	Length of Ingot Body	Weight, With Hot Top
4½ in.	15.52 sq.in.	16 in.	87 lb.
6	24.00	23	231
7½	46.02	32	453
9	66.50	34	750
12	127.05	42	1753
13	154.56	48	2240

contained in the data sheet, page 497, and from the data given one can readily compute the amount of each element entering the furnace and the percentage analysis of the mixture. From the analysis of the resulting ingot, and its weight (2358 lb.) the recovery of each element can be computed. These figures are contained in the table at left. Alloy losses will vary with the surface condition of the scrap, the method used in charging, sequence of alloy additions, slag treatment, and the type of cover used on the furnace during melting.

Fluxes charged comprised 8 lb. of silica clay, 12 lb. calcined lime, 4 lb. rock salt, and 4 lb. silicon-zirconium. Resulting slag analyzed 6.07% MnO, 0.036% P_2O_5, tr SO_3, 42.38% SiO_2, 3.50% Cr_2O_3, no WO_3, 4.20% FeO, 1.37% ZrO_2, 16.56% Al_2O_3, 20.04% CaO, 4.22% MgO, and 1.55% V_2O_5.

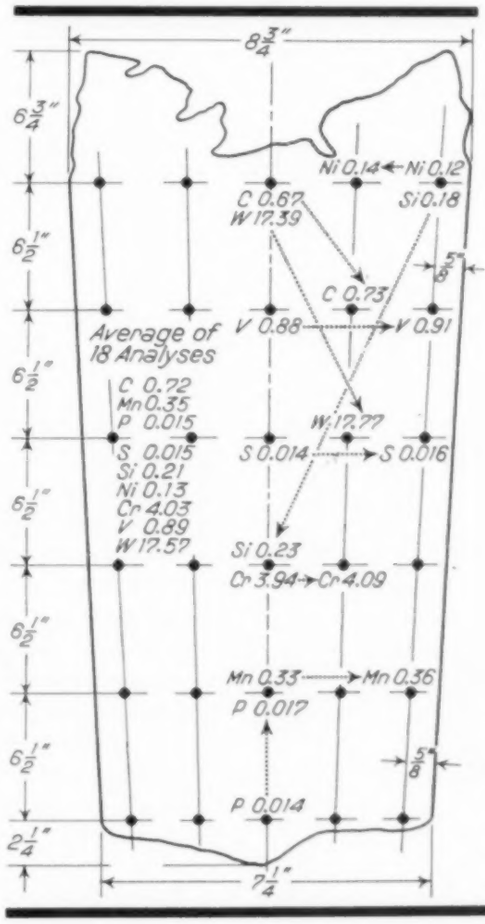
Ingot Practice

Whether an induction furnace or an electric arc furnace has been used in melting the steel, the same method is used in pouring—first into a ladle and then into ingot molds. The ingot molds are designed for the production of alloy steels and are prepared with great care in order to produce a sound ingot of high quality. Size of the ingot depends upon the composition of the steel, and whether it is to be hammered or rolled into billets. Commonly used square ingots for toolsteels, corrosion resistant steels, and alloy steels have sizes and approximate weights as shown in the table at foot of the previous page.

Composition of the steel and ingot size are factors which govern the casting temperature and rate of pouring. Temperature and rate of pour should be selected to produce a clean steel, free from gas cavities, center weakness or excessive segregation. In the case of high speed steels the effect of the casting temperature on the carbides must also be considered; in general, the carbides in a finished bar should be evenly distributed and as evenly divided as possible. Carbide segregation in the ingot should therefore be kept to a minimum. A high casting temperature means a long time for solidification in the molds, hence a greater opportunity for the carbide particles to grow. Slow solidification also causes larger volumes of eutectic (known as "carbide envelopes") thus giving coarser carbide particles.

Care must be taken not to cast the metal too cold. Too rapid solidification does not permit the inclusions to rise to the surface and the result would be a dirty steel; furthermore, it may cause a crust to form at the top of the ingot preventing the molten metal in the hot top from feeding the shrinkage cavity. This results in secondary pipe (internal shrinkage cavity). The sketch below represents the analyses taken on a 9x9-in. high speed steel ingot, cut longitudinally through the center, and indicates the high degree of uniformity in composition which is possible in steel from the induction furnace and the corresponding freedom from segregation.

All raw materials to be used in induction melting are carefully inspected and analyzed before being accepted. Typical analyses of some important raw materials are given in the large table in the data sheet, page 197. In most cases the analyses quoted give only those elements which are known to be of direct interest in calculating a charge.



A 9x9-In. Ingot of High Speed Toolsteel, Cut in Two, Was Sampled at 18 Points. Figures show maximum spread of analyses and approximate location of maximum and minimum. Vertical scale of sketch is considerably compressed

Ceramic Society members discuss most economical thickness of insulating brick, chrome-magnesite and olivine refractories, and the causes and correction of excessive slag attack. Steel base for enameling and its proper cleaning were also under scrutiny

Ceramists Ponder More Refractory Refractories

TAKING ACCOUNT of a spell of hot weather, a town noted for hot food and "hot spots," and a program devoted largely to high-temperature problems, the meeting of the American Ceramic Society held in New Orleans the week of March 28 is best described as a real hot meeting. The combination of business conditions and unusually long distance from centers of ceramic industry made some slight inroads on attendance, but at the same time, by a kind of selective action, assured that enthusiasm was high among those who did attend. This was nicely illustrated by the miniature camera fans, who though not as numerous as in other years, were more aggressive. One, in particular, insisted on jumping up and down in the technical sessions to snap the speakers. Perhaps, it was the heat after all!

Three of the four sessions of the Refractories Division were devoted to subjects of direct metallurgical interest, namely, insulating refractories, basic refractories and slag attack. The papers in these meetings, together with the lively discussion some of them evoked, amply justified the registration fee of $3.00, using as a basis the accounting system developed by Hoyt in the April issue of METAL PROGRESS.

Insulating Refractories

The session on insulating refractories opened with a paper of immediate practical importance by J. C. Crawford, Jr., of Johns-Manville, who outlined methods of calculating the most economical thickness of insulation to put on a furnace. It was somewhat surprising to hear a producer admit that there is such a thing as "most economical thickness," but it was shown that when one balances the increasing cost of insulation with increasing thickness against the cost of the heat saved, there is an optimum thickness at which the cost per annum is a minimum. The examples used were all ceramic kilns but the methods described are applicable to any other type of furnace.

Extensive measurements of the shrinkage of insulating refractories used as exposed furnace linings were reported by S. M. Phelps and E. C. Petrie of Mellon Institute. Shrinkage under such exposure, which occasionally proves troublesome, was determined by soaking heat tests in which the brick was placed in a furnace at uniform temperature and also by panel tests in which the panel is heated on one side only. The amount of shrinkage depends, as it should, upon the chemical composition of the brick and on the temperature to which it is exposed. What is less expected is that it should also depend upon whether the furnace atmosphere is oxidizing or reducing and, in the panel test, it is influenced by the relative gas pressure on the two sides of the panel.

By J. B. Austin
Kearny, N. J.

A paper by Carl E. Curtis of the Simonds Worden White Co. compared the porosity, permeability, load strength, and thermal conductivity of some commercial light weight refractories. The data showed that thermal conductivity decreases with increasing porosity, and that although there is a rough correlation between permeability and porosity, it is unwise to draw too detailed conclusions about one of these properties from measurements that have been made on the other.

Basic Refractories

The symposium on basic refractories was devoted largely to a discussion of the chrome-magnesite group, that is, refractories containing about 75% chromite and 25% magnesite. Basic materials originally attracted attention because they are more resistant to fluxing by iron oxide and lime, which are the most destructive agents above the bath level in an openhearth furnace, but they have a further advantage in that, being more refractory than silica or fireclay, they offer a possibility of higher refining temperatures.

A brief description of British experience with all-basic furnaces was given by J. H. Chesters of the United Steel Companies, Ltd., and T. R. Lynam of the Oughtibridge Silica Firebrick Co. This experience has so far been disappointing but not discouraging, for though the results are not satisfactory, it seems likely that the difficulties can be overcome by improved bricks. Chief among the difficulties were the low resistance of the bricks used to thermal shock, and their swelling, even bursting, due to absorption of iron oxide. Two cold metal furnaces, of the stationary type and 70 tons capacity, ran for 357 and 560 heats respectively although the furnace with 560 heats to its credit had to undergo some major repairs after 288 heats. Hot metal furnaces gave more promising results, presumably due to fewer week-end shutdowns and to the presence of less iron oxide in the furnace atmosphere. Tests showed the bricks used to be unsatisfactory for the roof, ports and downtakes, but entirely satisfactory for side walls. In one case walls of chrome-magnesite lasted 11 to 13 weeks as compared with 4 weeks for silica; this is economical even if no allowance is made for labor saved. The salvage value of the bricks is also high. Laboratory experiments by Chesters and Lynam showed that higher thermal shock resistance or lessened swelling can be obtained by changes in composition and grading of the raw materials. It may not be possible, however, to obtain both high shock resistance and low swelling in the same brick at the same time.

A study of olivine, and of forsterite refractories made from it, was reported by R. L. Stone of the University of North Carolina. Forsterite, a magnesium silicate having the composition $2MgO.SiO_2$, is a refractory material of recent introduction but of great promise. In this country it is made from olivine rock but in Europe it is usually prepared from serpentine minerals. In some cases olivine rock itself has been used in building furnace walls. Forsterite refractories have already been successfully used for the roof at the tapping end of copper reverberatory furnaces and for the entire roof in copper-holding furnaces. It has also been used for ports, uptakes, bulkheads and sidewalls of openhearth steel furnaces, but reports of its performance indicate that in such applications it has not been uniformly satisfactory. It is used extensively in England and Germany for reheating and forging furnaces. It fails by spalling or pitting, and according to Stone, these failures are largely due to incomplete conversion of the brick in manufacture. Better results are to be expected, therefore, from bricks made under more carefully controlled conditions.

A Ladle of Hot Metal — 40 Tons of it — Into the Openhearth. Photo by Charles M. Ward



Slag Attack

The first paper in the session on slag attack, sent from Berlin by K. Endell, R. Fehling and R. Kley of the Technische Hochschule, gave a comprehensive survey of the variables influencing corrosion of refractories by molten glass and slag. It was once thought that slag attack could be correlated with the melting temperature of the slag, but it is now recognized that there are other, and more important, variables, such as viscosity of the slag, hydrodynamic conditions in the furnace, the solubility of the refractory in the slag and the mobility of the dissolved material. Studies were made of all these factors.

Tests in which a standard fireclay refractory dipped into molten glass, or iron, copper or lead blast furnace slag, showed that if the refractory is in contact with a large body of slag, as it is in an openhearth furnace, the rate of attack is practically independent of the *composition* of the slag but increases markedly with increasing fluidity, and consequently with increasing temperature. If the slag drains in a thin film over a refractory wall, as it does in a boiler furnace or on an openhearth roof, other factors enter, chief among them being the solubility of the refractory and the mobility of dissolved material in the melt. The angle of inclination of the wall to the vertical has only a minor influence.

Two methods are recommended by the German authors for increasing the resistance of a furnace wall to corrosion by slag. The first is to use a refractory whose solubility in the melt is low. The second is to prevent the surface temperature of the wall from rising more than 50° C. above the melting point of the slag; if this is possible, a highly viscous protective layer of slag can be built up — formed automatically — which prevents the more fluid, and therefore more corrosive, body of the slag from coming in contact with the refractory.

Somewhat different conclusions were drawn by C. K. Donoho and J. T. MacKenzie of the American Cast Iron Pipe Co. from a study of the effect of fluxes on cupola linings. They also found that slag viscosity had a great influence on corrosion of the refractories but state that slag attack may increase with increasing viscosity, because a stiff slag has a high content of iron oxide and may, in addition, deflect the air blast directly against the lining. Statistical data on furnace repairs show *(a)* that in a limestone type of cupola flux some magnesia is beneficial in increasing the life of the lining; *(b)* that fluorspar, although harmful in itself, may, by increasing the fluidity of the slag, cause a net decrease in corrosion; *(c)* a small concentration of sodium carbonate in the flux results in longer life for the refractories.

One of the most novel developments announced at the meeting was the use of aluminum coatings on refractories, described by H. G. Schurecht of the New York State Ceramic Experiment Station. He reported that slag attack could be greatly lessened by spraying the refractory with molten aluminum or aluminum containing 10% ball clay. The resulting coating is converted to aluminum oxide either by prefiring or by the firing resulting from high temperature in service. This protective layer is very hard and has a faint odor of acetylene suggesting the presence of carbides. Direct tests at high temperature show increased resistance of coated refractories to attack by openhearth and blast furnace slag, and indicate a promising future for this type of material.

Of Interest to Enamelers

All the papers of metallurgical interest were not presented before the refractories division, however; as usual, the enamel division had its share. F. R. Porter of the Inland Steel Co. reported the results of tests on the sag-resisting properties of enameling iron, describing the method of test in detail. Sag increases with increasing temperature and decreasing gage. It is also greater in mild carbon steel than in enameling iron.

The efficiency of inhibitors in pickling was discussed by C. P. Weise of the Grasselli Division of E. I. du Pont de Nemours & Co. He pointed out that the use of inhibitor lessens the attack of pickling acid on iron sheets and therefore results in only a light etch of the metal, whereas a deeply etched surface is desired on enameling stock to aid adherence. He suggested that for enameling iron the normal pickling operation should be followed by a controlled deep-etching bath.

In conclusion, it should be stated that there was a remarkable absence of the new streamlined, self-filtering, automatic-bailing cigarette holders. One or two were much in evidence, but it was gratifying to realize that in a civilization which shows not a few signs of fatty degeneration, the brickmakers, as a class, are still virile enough to take their tobacco straight.

Raw Materials for Tool and Alloy Steels

As Made in Crucible, Induction and Basic Arc Furnaces

H. C. Bigge

Refractories	C	MnO	P_2O_5	SO_3	SiO_2	Cr_2O	Al_2O_3	Fe_2O_3	CaO	CaF_2	MgO	Ignition Loss
Dead burned magnesite, "Arc"	....	....	....	....	4.58	....	6.45		2.36	....	85.80	0.48
Magnesite, "Arc"	....	....	....	....	4.64	....	....	12.58	46.68	....	32.11	1.20
Basic slag, binder for magnesite	0.40	8.74	2.05	0.25	17.24	0.80	4.67	13.20 FeO	43.21	3.46	5.60	....
Arc furnace, roof brick	....	....	....	....	53.00	....	42.00	1.25	....	....	....	....
Magnesite brick for bottom	....	....	....	....	3.90	....	0.30	1.30	1.50	....	92.30	0.70
Silica brick side walls	....	....	....	....	95.50	....	1.00	0.90	2.00	....	....	....
Magnesite crucible, induction furnace	....	....	....	....	10.12	....	3.50	1.02	2.68	....	82.35	....
Fused magnesite for packing induction furnace	....	....	....	....	5.46	....	2.33	1.07	2.05	....	88.76	....
Crucible for fuel fired furnace	49.86	....	....	....	33.27	....	14.74	3.44	0.62	....	1.01	....
Inner lining of above	0.45	....	....	....	84.10	....	3.18	11.23	0.42	....	0.34	....

Pig Iron, Iron, Alloy Scrap	C	Mn	P	S	Si	Ni	Cr	Cu	Fe	W	V	Others
Electrolytic iron	0.005	None	None	0.006	None	None	None	0.006	99.989	....	....	....
Muck bar	0.050	0.050	0.015	0.020	0.030	None	None	0.025	99.810	....	....	....
Charcoal iron	0.050	0.030	0.020	0.025	0.030	0.030	0.03	0.080	99.715	....	....	....
Openhearth iron	0.050	0.030	0.020	0.025	0.030	0.030	None	0.10	99.715	....	....	....
Openhearth remelt	0.050	0.100	0.025	0.025	0.050	0.080	0.050	0.15	99.470	....	....	....
Low phosphorus pig iron, a	4.130	0.120	0.019	0.013	0.870	None	None	None	....	....	....	....
Low phosphorus pig iron, b	3.850	0.520	0.028	0.014	0.300	....	....	0.23	....	....	....	....
High speed steel, 18-4-1	0.75	0.25	0.016	0.023	0.15	0.08	4.00	....	....	18.00	1.00	....
14-4-2	0.70	0.25	0.025	0.025	0.35	0.10	4.00	....	....	14.00	2.00	....
18-4-2	0.75	0.25	0.025	0.025	0.35	0.10	4.00	....	....	18.00	2.00	0.80 Mo
Cobalt	0.75	0.25	0.025	0.025	0.35	0.10	4.00	....	....	18.00	1.50	5.00 Co
Special tungsten steel ingots	0.50	0.10	0.020	0.020	0.20	0.05	....	....	....	14.00	....	....
28% chromium-iron	0.20	0.80	0.025	0.025	0.80	0.50	28.00	....	....	....	....	....
17% chromium-iron	0.10	0.40	0.025	0.025	0.35	0.50	17.00	....	....	....	....	....
18-8 stainless steel	0.06	0.40	0.025	0.025	0.35	8.50	18.50	....	....	....	....	....

Fluxes	SiO_2	FeO	Al_2O_3	Fe_2O_3	CaO	$CaCO_3$	CaF_2	MgO	$MgCO_3$	S	SO_3	Ignition Loss
Pebble calcined lime	1.36	....	0.40		96.48	....	....	1.13	....	....	....	0.63
Limestone	1.20	....	1.54		....	94.80	....	....	2.30	....	....	....
Cement clinker	21.76	....	4.50	3.11	66.05	....	....	3.00	....	....	0.42	0.85
Fluor spar (lead free)	3.90	Trace	Trace	....	0.41	0.71	94.65	0.14	....	0.05	....	....
Silica Clay	62.47	....	21.30	15.68	0.43	....	....	0.12	....	....	....	....
Silica Pebbles	98.70	1.20	....	....	....	....	....	....	....	0.027	....	....
Silica Sand	98.74	....	1.04	Trace	....	....	....	Trace	....	....	....	0.13

Ferros and Alloying Metals	C	Mn	P	S	Si	Ni	Cr	V	Cu	Mo	Others
Ferrosilicon, 15%	0.23	0.24	0.09	0.014	15.74	....	....	....	....	....	....
50%	0.12	0.35	0.040	0.044	48.46	....	....	....	....	....	....
75%	0.06	0.12	0.037	0.015	76.37	....	....	....	....	....	....
Cobalt metal	0.13	0.15	....	0.02	....	0.24	....	....	....	....	99.24 Co
Ferrotungsten	0.35	0.59	0.018	0.052	0.56	....	....	....	0.035	....	78.39 W
Ferrotitanium, low carbon	0.08	....	....	....	4.24	....	....	....	....	....	41.46 Ti
Ferrocolumbium	0.24	3.44	....	....	6.62	....	....	....	....	....	57.65 Cb
Magnesium-nickel	0.06	....	....	0.04	0.09	33.71	....	....	....	....	66.05 Mg
Ferromolybdenum, low carbon	0.07	0.08	0.054	0.046	1.02	0.09	....	....	0.28	61.70	....
Ferrovanadium, low carbon	0.21	0.38	0.065	0.10	1.31	0.10	....	40.84	....	....	....
High carbon	3.02	0.08	....	....	11.80	1.86	....	40.80	....	....	....
Iron pyrites	0.12	0.18	0.012	32.80	....	....	....	....	....	....	66.89 Fe
Ferroselenium	1.60	.23	....	....	1.21	....	....	....	0.03	....	56.75 Se
Calcium molybdate	0.20	....	....	0.32	3.00	....	....	....	....	41.45	....
Ferrochromium, low carbon	0.06	0.40	....	....	0.08	....	71.54	....	....	....	....
High carbon	5.20	0.18	0.044	0.017	1.74	....	69.36	....	....	....	....
Ferromanganese, low carbon	0.65	83.65	0.25	0.035	5.37	....	....	....	....	....	....
High carbon	6.54	79.60	0.25	0.068	1.38	....	....	....	....	....	....
Spiegeleisen	5.22	21.16	0.034	0.044	2.42	....	....	....	....	....	....

Powdered Deoxidizers for Slag	C	Mn	P	S	Si	Zr	Ca	Mg	Fe	Ash	Volatile
Coke	88.52	....	0.008	0.490	....	....	....	....	....	9.420	2.06
Ferrosilicon, 80%	0.06	0.28	0.03	0.015	82.67	....	....	....	16.95	....	....
Silicon-zirconium	0.23	....	....	....	54.75	39.04	....	....	4.24	....	....
Silicon-calcium	0.13	....	....	....	60.81	....	33.59	....	2.46	....	....
Silicon-calcium-manganese	0.14	15.42	....	....	57.71	....	18.98	....	5.82	....	....
Calcium metal	....	....	....	....	....	....	98.50	....	....	....	....

PERFORMANCE SUSTAINED...



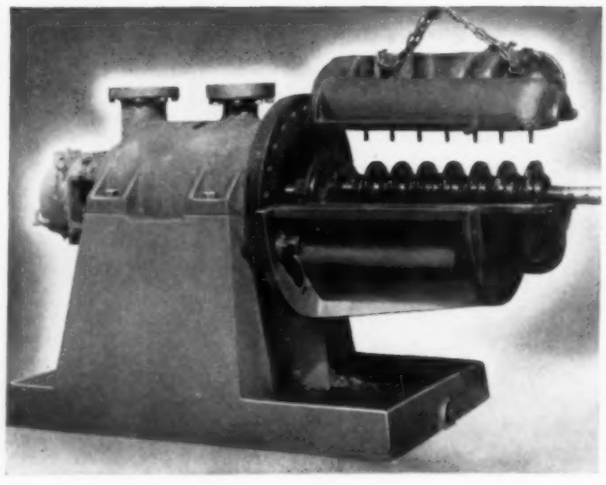
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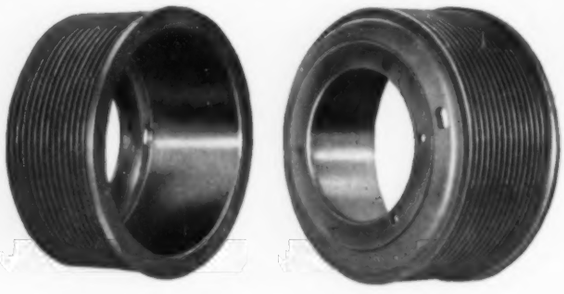
NICKEL CAST IRONS

...Wear and stress and corrosion-resistant cast irons prove their worth in diverse applications

PUMP CASING RESISTS HARSH ABRASIVES

This pump casing on a dredge in San Diego harbor has handled 3,200,000 cubic yards of material averaging 5% rock, 20% gravel, 10% silt. Owners estimate it good for 1,000,000 yards more. Made by Golden State and Miners Iron Works Co., of alloy cast iron containing 1.50 to 2.00% Nickel and about 0.50% chromium.





TAKES THE BRUNT OF 16,000 STOPS AT 50 M. P. H.

Research by leading bus and truck manufacturers proves 2% to 2½% Nickel-chromium cast iron the ideal brake drum material for high-speed, heavy-duty vehicles. In severe tests simulating road braking conditions, with 200 stops at 80 m.p.h. and 16,000 stops at 50 m.p.h., wear on the drum was only 0.002, with no scoring despite temperatures over 800 deg. F.

WITHSTANDS CORROSION FROM CRUDES

For nine months this pump has continuously discharged Gulf Coast crude, with a specific gravity of 76 at 750 deg. F., 1100 p.s.i. Says the manufacturer, Byron Jackson Co., Los Angeles, "The entire output of the plant has been handled by this pump, and undoubtedly a great deal of coke and sediment has passed through this unit, yet the Nickel cast iron inner case shows no noticeable effects of either corrosion or erosion."

Additions of small amounts of Nickel render cast iron uniformly hard, tough and wear resisting, yet capable of being machined and ground to a smooth, glossy finish. Consultation on problems involving the use of Nickel cast irons and other Nickel alloys is invited.

THE INTERNATIONAL NICKEL COMPANY, INC., NEW YORK, N. Y.

Cool metal, loaded so it stretches slightly, will automatically be strengthened and movement will stop. If metal under such load is continually heated so this strengthening effect is exactly counterbalanced by recrystallization, creep continues indefinitely. Failure results only when the softening effect predominates.

High Temperature Strength of Steels

IT HAS LONG BEEN KNOWN that tensile fractures in steels produced by slow loading at ordinary temperatures are propagated through the "grains" whereas the fractures at high temperatures follow the boundaries. Such observations led to inquiries concerning the nature of the material within the grains and between the grains. The grains themselves are crystalline material in which the atoms are arranged in space in orderly geometric fashion. On the contrary, the material between the grains is in a state of disorganization with the atoms in random arrangement — or at least under the combined influences of the crystallizing forces of the neighboring grains. When stretched beyond the elastic limit, the grains deform by slip on favored crystallographic planes, but the intergranular material oozes like a vitreous amorphous solid or a super-cooled liquid.

At higher temperatures the amplitude of vibration of the atoms increases so that both the crystalline and intergranular materials gradually lose strength due to reduced atomic cohesion, the crystalline grains less rapidly because the rigid framework of the crystal structure restricts free movement of the atoms. Since at low temperatures the material in the grain boundaries is stronger than the grains and at high temperatures the grains are stronger than the intergranular material, there must be some point on the temperature scale at which these two phases have the same strength. This point has been called the equi-cohesive temperature.

"Cohesion" may be taken in the sense of elastic limit, or maximum stress sustained without permanent deformation. But the elastic limit of the intergranular material depends on the rate of loading — it behaves like pitch, a viscous liquid. Equi-cohesive temperature, in this sense, also depends on rate of loading; with rapid rates of loading the intergranular material shows high instantaneous strength, and the equi-cohesive temperature is high.

By applying loads extremely slowly the lowest temperature of equi-cohesion can be determined — most important in considering the strength of hot steels because the intergranular metal is stronger than the grains below the lowest temperature of equi-cohesion and consequently all the customary stress-strain relationships at ordinary temperatures can be expected to prevail up to that point.

A satisfactory procedure consists in simply fracturing specimens in tension under controlled conditions and assuming that failure occurred in that phase which had first passed its elastic limit. Micrographs by White, Clark and Wilson (*Transactions* ⊕, Vol. 25, p. 863) show the

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Full Extracts from a paper before the Western Metal Congress

microstructure normal to the surface of fracture of test pieces broken at 1000° F. after different rates and periods of straining. It is evident that 1000° F. lies above the equi-cohesive temperature of low carbon steel, but below that of the low alloy steel, for in the latter case the grains are elongated and the fractures trans-granular even after a slow loading requiring 6151 hr.

It is evident that the lowest temperature of equi-cohesion is not the same for different steels, but will vary with the chemical composition. The lowest temperature of equi-cohesion for low carbon steel seems to lie between 650 and 750° F., as determined by the first signs of appreciable viscous flow. Alloying elements such as chromium, tungsten, and molybdenum appear to raise this temperature, although quantitative data on this point are scarce.

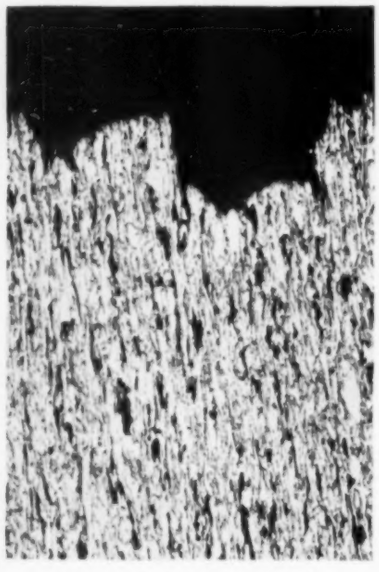
Short time tensile tests at high temperature are conducted in much the same manner as tensile tests at ordinary temperatures. The furnace must supply heat uniformly and have good temperature regulation; specimens under test should be kept at temperature prior to loading to insure thorough soaking; and finally the rate of loading should be standardized. Below the lowest temperature of equi-cohesion the *rate* of loading does not have much effect, but at higher temperatures (as will be shown later) the figures derived for the ultimate strength and the ductility are greatly affected by the speed of testing.

The influence of temperature on the short-time tensile properties of a low carbon steel is illustrated by a figure reproduced on the right-hand page from data of F. W. Martin in the A.S.T.M.-A.S.M.E. Symposium on the effect of temperature on the properties of metals (1931).

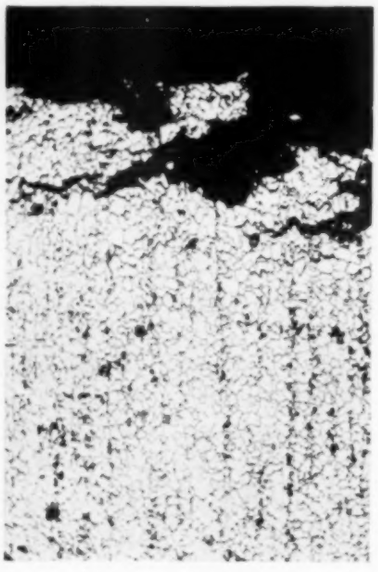
For service applications of steels at temperatures below the lowest temperature of equi-cohesion, there is no reason why reliable designs cannot be based upon the yield or ultimate strength as determined in this way. In fact, this would be little different from the present practice of designing on the tensile strength at 70° F. with a suitable factor of safety, because in many instances the short-time ultimate strength up to about 750° F. is nearly the same in numerical value. Sometimes the short-time properties at 1000 to 1500° F. are helpful in interpreting conditions arising from the overheating of pearlitic steels in service.

Variations in Nature of Fracture With Temperature, Time of Loading, and Nature of Steel

Low Carbon Steel Broken at 1000° F.

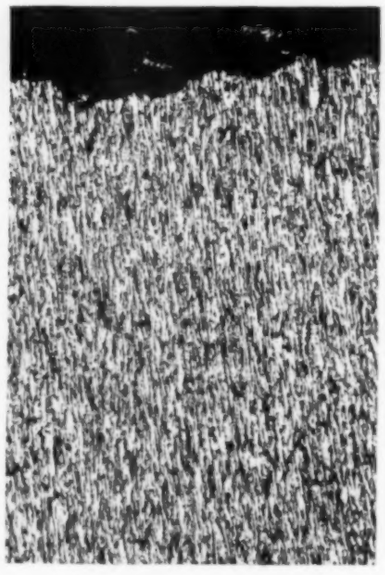


Short Time Tensile Test;
Broke at 36,500 Psi.

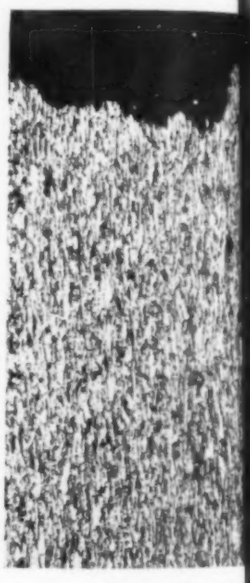


6000-Psi. Initial Stress;
Broke After 13,950 Hr.

Low Alloy Steel (Cr-Si-Mo) Broken at 1000°F.



Short Time Tensile Test;
Broke at 57,750 Psi.



24,600-Psi. Initial S
Broke After 6151

Flow or Creep of Steels

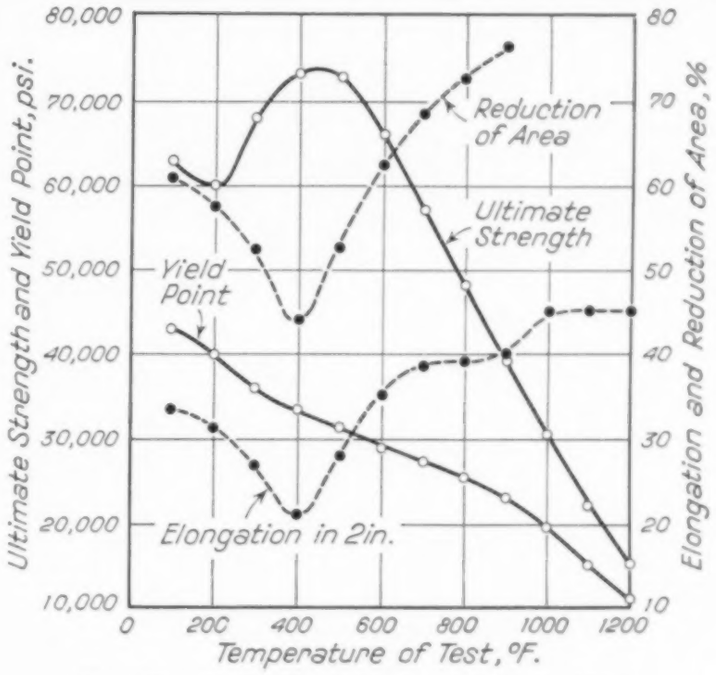
Above the equi-cohesive temperature the effect of *time* first becomes a significant factor, since deformation does not remain constant but increases continuously, so that steels "flow" or "creep" even under small loads. High temperature strength must therefore be expressed in terms of temperature, stress, rate of deformation, and time.

This flow has been explained variously with some confusion of nomenclature if not of fundamental ideas. Nevertheless, it has been pretty generally agreed that the creep of steels under very small stresses is almost purely viscous flow, like the slow movement of a stiff liquid. Since the intergranular material is a continuous phase in a metal, this view is quite plausible. Faster rates of movement are not regarded as viscous flow alone and have often been called plastic flow, although it seems most reasonable to suppose that these deformations are partly viscous and partly plastic. (The word "plastic" would be defined for this purpose as the deformation of crystals by slip, not as the type of flow exhibited by "plastic solids" such as clay.)

According to this supposition, creep of steels under small stresses above the equi-cohesive temperature takes place by the viscous flow of the intergranular metal, which is the weaker phase in this temperature range for very slow rates and long durations of loading. For faster rates of loading the viscous intergranular material possesses some degree of rigidity, thus permitting the transfer of stress to the crystalline grains where permanent deformations take place by slip. A small amount of viscous flow always accompanies the plastic deformation of the grains because the intergranular metal is capable of transmitting stress while in creep movement. For all except the smallest stresses, then, creep strain is the combined result of viscous and plastic flow, with the plastic deformation greatly predominant for rapid rates of loading.

Plastic deformation at ordinary temperatures causes strain hardening, which can be relieved by heating to what has been called the recrystallization temperature. Presumably a steel cannot be strain hardened by deformation at temperatures *above* this recrystallization temperature because the hardening effect would be nullified by the simultaneous annealing. If so, the position of the recrystallization temperature will depend upon the rate of deformation. The lowest temperature of recrystallization, corresponding to an extremely slow rate of deformation, is theoretically the same as the lowest temperature of equi-cohesion.

For the slower rates of deformation it has been observed that at each temperature there is only one stress capable of producing steady creep at the same rate for long periods. In such instances the annealing tendency just balances the strain hardening tendency, and the extension proceeds without change in the mechanical properties of the steel. With higher stress fracture would take place eventually, while with lower stress perceptible creep would stop through strain hardening. This remarkable equilibrium is shown in the curves on the next page, typical for steels under different constant loads at elevated temperatures.



Short-Time Tensile Properties of Low Carbon Steel Show a Brittle Range at 300 to 500° F., but Little Loss in Strength up to the Equi-Cohesive Temperature (700° F.)

Part *O-I* is the reversible elastic strain that occurs immediately after loading; the piece would return to its original dimensions if the load were removed instantly.

Creep begins at *I* and *I-S* is known as the "initial stage of creep" because during this period the rate of creep is decreasing. The shape of the curve between *I* and *S* is attributed to the distribution of stress and the strain hardening incidental to the application of load. Uneven stress distribution at the beginning is due to the anisotropic character of the crystalline grains of the steel — that is to say, they show different physical properties if tested in different directions inclined to the principal axis of the crystal. Some grains in the random grouping across any cross-section will be more favorably situated than others, and the stiffer ones will carry the load at first, but as they deform the load will be distributed among some others. The net effect is the same as though the material were actually becoming stronger, with the result that the amount of creep decreases. At the same time, the strain hardening accompanying the plastic deformation increases strength to some degree and thus contributes toward decreasing creep.

Creep at Constant Rate

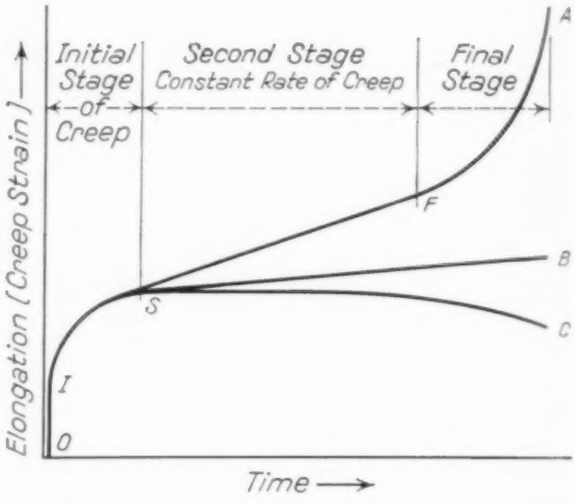
The second stage of creep in an overloaded specimen takes place between points *S* and *F*, and is characterized by the constant rate already mentioned. During this period the annealing effect becomes noticeable as it counterbalances strain hardening.

Part *F-A* is the final stage of creep in which the rate becomes faster and faster until fracture occurs. The annealing effect plays an important part at this time but does not always predominate, because the increase of the unit stress in the contracting section adds to the strain hardening effect as the piece approaches rupture.

Curve *O-S-B* represents a condition of loading in which, after the initial deformation, creep proceeds at constant rate under uniform stress for very long periods of time; the steel never enters the third stage of creep and hence will not fail. Steels under small loads and heated somewhat above the equi-cohesive temperature will behave in this manner.

Curve *O-S-C*, which is slightly concave downwards after a long period of time, is the special case of small loads just above the equi-cohesive temperature where the rate of annealing is exceedingly slow and the initial strain hardening so strengthens the steel that creep will stop altogether. The case for "negative creep" implies that stress distribution is continuing on a small scale, perhaps permitting some creep recovery.

Duration of these three stages will vary greatly depending upon the steel itself, the temperature of the test, and the initial unit stress. Actual tests on a low alloy steel have shown that the constant rate of creep during the second stage is the minimum creep rate for each stress.



Steel Carrying Small Loads Above the Equi-Cohesive Temperatures May Creep at a Steady Rate for a Long Time (Curve B) if Annealing by Recrystallization Exactly Counterbalances Strain Hardening. Higher loads cause eventual failure (Curve A) and lower loads cause "negative creep" (Curve C)

In estimating the high temperature strength of steels for design purposes, the problem involves the permissible limitations on either deformation or stress. Sometimes the details of engineering construction may limit the dimensional changes of certain parts to very small total for a period of years; in other cases reasonable creep can be tolerated but the steel must be capable of sustaining definite stresses safely for a given time. The first class of applications includes certain turbine parts, valve parts, and bolting, while the second class comprises superheater tubing, pressure vessels, and tubular process coils for the chemical and oil industries. These requirements are being met

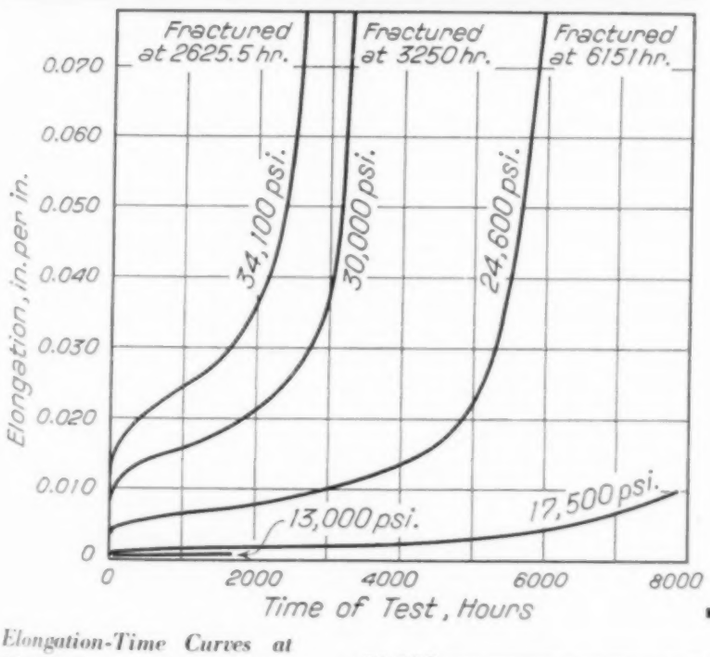
for the first class of applications by determining the tensile creep strength and relaxation properties of the steels, and for the second class by creep tests and stress-rupture tests.

Creep strength of a steel is the unit stress that will produce steady flow at a definite rate at a stated temperature. It is determined by observing the creep of tensile specimens under three or more stresses at each temperature of test, so chosen as to cover approximately the creep rates of particular interest. After the specimens have started to stretch uniformly in the second stage of creep, the rate of creep for this portion of the curve is established by graphics or mathematics. Thereafter unit stress can be plotted against rate of creep on log-log coordinates as shown in the accompanying graph, and strength values corresponding to arbitrary creep rates can be interpolated. In determining creep strength by this method it is preferable to keep the specimens under stress for long periods, say 1000 to 3000 hr. The rate of creep should then be established on the observations during the last 500 hr. of the test.

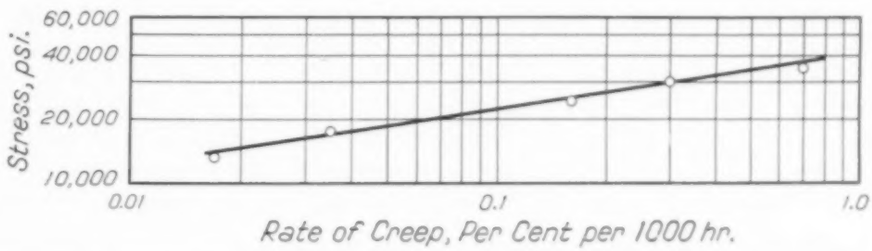
It is customary to speak of the "creep strength that will produce creep at the rate of 1% in 100,000 hr." (or 1% in 10,000 hr.). As all creep tests are conducted for comparatively short times in relation to the period of anticipated service, the suggestion has been made to designate these same creep strengths as the stresses that will produce creep at the rate of 10^{-7} and 10^{-6} in. per in. per hr., respectively. Basing creep strength on the uniform rate of creep attained in the second stage of creep may seem to be ignoring the initial deformation, which at times may be large. On the contrary, as smaller test loads are chosen in the creep tests the deformation in the first stage of creep becomes very small and may be neglected without serious consequences when the creep strength is determined by using stresses that will produce creep at an hourly rate somewhere near 10^{-7} in. per in.

The relaxation test used to determine the suitability of bolting materials for high temperature service is a modified form of creep test, wherein the extension is fixed at the start by the tension on the bolt and remains the same, being originally the elastic strain resulting from the stressing. The initial stress is then gradually reduced with lapse of time by the substitution of plastic for elastic strain.

As already noted, the tensile strength at temperatures above the equi-cohesive depends upon the rate of loading. When the latter is so slow that fracture only takes place after a great interval of time, the ultimate strength will be at about its minimum value, which can therefore be called the "long time tensile rupture strength." This test has become recognized as a useful measure of



Elongation-Time Curves at 1000° F. for Five Stresses, and Rate of Creep at 1000 Hr. Plotted on Log-Log Paper. Steel contained 0.07% C, 0.42% Mn, 0.72% Si, 1.25 % Cr, 0.54% Mo. (White, Clark & Wilson, Proceedings A.S.T.M., 1935-II; p. 167)

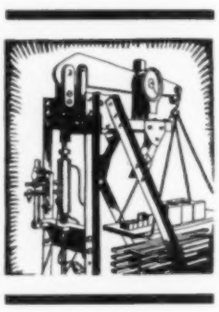


strength at high temperature, and has been applied successfully for years in the design of certain types of equipment. It pays no attention to the amount of deformation.

The method of estimating the long-time tensile strength was described by T. McLean Jasper before the American Petroleum Institute in 1927. Specimens of a steel are subjected to a series of decreasing loads, producing progressively smaller initial unit stress in the test pieces, and the time required for fracture is observed. White, Clark and Wilson in their paper in 1937 showed that if the relation between stress and time for rupture in the long-time tensile test is plotted on logarithmic coordinates, the points fall on a straight line. From such extrapolations the long-time strength values can be estimated for rupture in 10,000 hr., 25,000 hr., or longer periods. The method, its utility and limitations, is explained in an article for the Western Metal Congress on "Stress-Rupture Test" by White, Clark and Hildorf published in METAL PROGRESS for March.

Intergranular Cracking

The only circumstances in which the extrapolation of the logarithmic curves is not dependable occur when the steel develops intergranular oxidation in the course of the test and as a consequence lower strength values are observed than would be predicted. Intergranular oxidation of steel should not be regarded as something different from the intergranular cracking mentioned by the English investigators Jenkins, Tapsell, Mellor and Johnson in a paper entitled "Some Aspects of the Behavior of Carbon and Molybdenum Steels at High Temperature" before the World Power Conference in England (1936).



Both phenomena are the result of certain conditions of heating and stressing that may happen in either creep tests or long-time tensile rupture tests. There seems little doubt that stressing a steel at high temperature in an oxidizing atmosphere will aid gases to penetrate between the grains. The main question, of course, is whether the separation of the grains is started by the growth of the intergranular oxide layer or is caused by a two-stage process in which intergranular cracking is followed by the oxidation of the walls of cavities so formed.

Instances are known of intergranular oxidation at the surface of specimens that is not accompanied by cracking between the grains on the interior of the pieces. Contrariwise, there are examples of specimens in which the microstructure throughout a cross-section exhibits intergranular cracking without pronounced oxidation at the surface. Upon careful consideration of the data it appears justifiable to conclude that failure by intergranular cracking should be expected in all steels subjected to comparatively slow rates of flow under stress. It is conceivable therefore that, with different conditions of heating and stressing, surface intergranular oxidation may occur alone, intergranular cracking and oxidation may take place together, or, in the last place, intergranular cracking may occur without oxidation.

If the possibility of intergranular cracking is associated with the rate of flow rather than the stress intensity, the effect of stress cannot be considered independently of temperature. These intergranular failures involve principally the viscous properties of the steels, which, being largely crystalline, behave differently from the wholly amorphous materials in that metals broken by small loads acting for long periods of time show little if any elongation, whereas amorphous materials like pitch or glass show more elongation the slower the loading.

Since steels fail by intergranular fracture after long times under load, it is not surprising to find the elongation decreasing as the time for rupture is extended. On the other hand, it is not so obvious that the falling strength with time for rupture and the intergranular cracking are both caused by the viscous nature of the material. Yet this view seems preferable to the belief that intergranular cracking is responsible for the lower strength. It must be remarked, however, that the presence of intergranular oxidation does definitely reduce the long-time strength of steels.

Strengthening of Steels

In any consideration of the strength of steels at high temperature it is quite natural to speculate upon what makes steels strong at high temperatures and how the different chemical elements exercise their influence in improving strength under these conditions.

From what has already been said, the supposition can scarcely be avoided that strength at high temperature could be increased by doing anything that would raise the lowest temperature of equi-cohesion or recrystallization. This seems to be the mechanism by which simple pearlitic steels acquire greater resistance to creep through the addition of elements such as tungsten, vanadium, chromium and molybdenum. The superior strength of the austenitic chromium-nickel stainless alloys over the plain high chromium steels may likewise be attributed to their higher temperature of recrystallization found after the phase change produced by the nickel additions.

Raising the lowest temperature of equi-cohesion or recrystallization also raises the upper limit to which the short-time tensile properties can be used as a reliable index. It is in the range from atmospheric to the equi-cohesive temperature that substantial gains in strength can be developed through raising the carbon content of steels and resorting to heat treatments. For example, plain carbon steel for service up to about 900° F. can be strengthened by raising the carbon content. A still stronger material for service at 900 to 1000° F. could then be obtained by adding molybdenum and giving the steel a proper normalizing and tempering treatment. Nevertheless, there might be practical reasons why these suggestions should not be followed. Not much can be done to increase the creep strength of steels for very slow rates of creep at temperatures above the recrystallization temperature. Heat treatments have helped in some cases of moderate rates of creep and perhaps more can be accomplished on further study. Whatever would confer greater viscosity on the intergranular phase in metallic aggregates at these temperatures would automatically increase the creep strength. The effect of adding silicon to steels resembles this action in some respects.

In concluding this discussion, it may be said that the literature now contains a great number of strength data suitable for use in designing various kinds of equipment for service at elevated temperatures. The nature of the applications will in each case impose limitations on the maximum permissible deformation or working stress, but once these conditions are known the manner in which the high temperature strength should be measured will be apparent, and the proper data can be obtained to conform with the requirements.

The Cost of Steel

By John Johnston

Extracts from an address entitled "Steel"; Journal of the Franklin Institute, April 1938, p. 373

THE PRIMITIVE METHOD of making steel made use of forges or furnaces so small that the output of a man could readily be reckoned in terms of ounces per day, or even per year. Correspondingly, the cost of a steel article, in terms of the number of days which an ordinary man would have to work to accumulate enough to pay for it, was so high that steel could be used only for very special purposes. On this small individual scale the primitive method persisted until about 500 years ago — indeed it is still in use today in many parts of the world.

The progressive advances in the scale of the art — brought about by a large number of men, many of them now forgotten — resulted in a gradual lowering of the real cost of steel, consequently in an increased production and a wider usefulness. But during the greater part of this period, the production could well be reckoned in pounds; a century ago the total production of pig iron in this country was only about 250,000 tons a year. Production increased gradually until the decade 1860-70, when the invention and utilization of the bessemer converter and of the openhearth furnace brought about a greatly accelerated rate of annual production of steel. The outcome is that an annual production in the United States of decidedly less than one million tons 60 years ago increased to some 20 million tons 30 years ago and is now nearly 50 million tons. At the same time the price of steel per ton has dropped from about $150 to $60; that is, in 60 years it has dropped to 40% of what it was in terms of dollars, and to less than 20% on the basis of the buying power of the average citizen.

This greatly increased rate of production and the cheapening of the product which enabled consumption of steel to expand so greatly was made possible by the use of larger and better integrated units, and this in turn by cutting down by increased mechanization the amount of strenuous labor previously involved in many of the steps in the making of the multifarious steel products now required. It now looks as if no further **appreciable** lessening of the dollar cost of steel is possible through the use of still larger units or of further mechanization.

(Continued on page 538)

Letters and Comment

Influence of Lining on Quality of Induction Furnace Steel

TURIN, ITALY

To the Editor of METAL PROGRESS:

Comparatively little information has yet been published in Europe concerning the practical operation of steel furnaces of the coreless induction type. A survey of published data, supplemented by private information, gives the impression that really standardized practices have not yet been established. This last fact may, perhaps, account for the widely different opinions concerning the utility of this type of furnace for different classes of steels.

It would take too long to recount the details of the very different working conditions of lately installed coreless induction steel furnaces in Europe, but a few data may be sufficient to give a general view.

Obviously, the widely differing types of electrical equipment used in the different plants may have only a very limited influence on the metallurgical results — with the exception, perhaps, of the different frequencies of current. However, the influence of this last element must be confined to the electrical and thermal efficiency of the system, and therefore can only affect the economy of production. The claim, often repeated, that current frequency may have an indirect influence on the metallurgical processes through its influence on the circulation in the molten bath, does not seem to be confirmed by the actual results in practice.

Quality of refractory lining seems to influence the quality of products to a much greater extent in the case of induction furnaces than with other types of furnaces. To substantiate this is the fact, acknowledged by practically all European plants, that good transverse elongations and impact resistances are difficult to obtain with steel from acid induction furnaces.

Many explanations have been offered for this fact, mostly based on the different ratio of temperatures of slag and metal in induction furnaces, when compared with the temperatures prevailing in all other types of furnaces. The practical consequence is that acid linings in European induction furnaces are almost wholly confined to the manufacture of toolsteels.

Some difficulties were experienced, in the beginning, in obtaining a good basic lining.

In some plants, especially in France and Germany, the old process is still used. This consists of a strongly rammed basic mixture, containing a certain proportion of clay (as a binding agent) and the quantity of water necessary to give a sufficient plasticity to the mixture. The rammed lining is then simply dried before receiving the first charge.

This very economical procedure has gradually been replaced by others, more expensive, but securing a better lining, as far as resistance to heat, shock and scour is concerned. In these processes the refractory granular mixture is used dry, and only lightly rammed around a metallic form. The latter is then heated gradually by induction, and melted. Under such conditions the lining is gradually and thoroughly baked, and the high proportions of binding materials can be avoided. A special refractory material containing alumina and zirconium oxide has been adopted by many steel works, and gives excellent results.

The number of heats obtained in Europe with a basic lining varies, naturally, within wide limits, according to the raw materials used, the type of furnace, the quality of steel manufactured, and other factors. But under the more common conditions, 150 to 200 heats are considered a good campaign. A heat will generally take from 2 to 3 hr. in furnaces of 4 to 8 tons capacity.

Very small furnaces have been abandoned (except for experimental purposes) as being uneconomical. The most popular sizes are 2 to 6 tons capacity. As a consequence of the above-mentioned improvements in the preparation of basic linings, larger sizes (up to 12 tons) have been recently installed in a few plants.

FEDERICO GIOLITTI
Consulting Engineer; Bessemer Medalist

A Calorimeter, As Was

QUINCY, MASS.

To the Editor of METAL PROGRESS:

I am enclosing a photograph of what at first sight appears to be a beer mug. Perhaps there are many old timers who will recognize it immediately. Nevertheless, I am sure there are youngsters who would be interested to know that it is a *pyrometer*. No fooling!

The piece of apparatus is somewhat similar to a calorimeter used for an experiment in physics. To measure temperatures, a small cube of copper of known weight is placed on the bar to be heated, and when the copper is at the same temperature as the bar it is quickly quenched in a fixed quantity of water held in this calorimeter can. The latter is insulated to cut down heat loss by radiation, and the temperature of the piece to be heat treated is calculated from the rise in temperature of the water. It can possibly be seen from the engraving that 50° F. difference in furnace temperature is only about $\frac{1}{32}$ in. on the calorimeter scale!

In nearly 40 years at the forge shop of Fore River shipyards (now Bethlehem Shipbuilding Corp.), a number of changes similar to the advance in ease and accuracy of temperature measurement have been observed. The two contrasting pictures on pages 451 and 455 of last October's METAL PROGRESS also emphasize this same point — one shows the means used by Taylor and White in their research on high speed steels at the turn of the century, and the other is a modern optical pyrometer.

Had these pioneering investigators been able to find a rugged and thin-walled protection tube, they probably would have used a Le Chatelier thermoelectric pyrometer, as this had been perfected at least ten years previously. However, it was still a piece of equipment for an advanced laboratory rather than for a heat treatment or forge shop. For a long time about the only thing we had, other than the educated human eye, was this calorimetric pyrometer, first made for industrial purposes, according to Professor Goodale's "Chronology of Iron and Steel," by Byström in 1862.



Siemens Calorimetric Pyrometer or "Water Pyrometer" Widely Used Not so Long Ago by Furnace Foremen of a Scientific or Skeptical Turn of Mind to Check Human Eye Estimates

ED. B. ASHWORTH
Foreman, Forge Shop
Bethlehem Shipbuilding Corp.

Conductivity of Copper

NEW YORK CITY

To the Editor of METAL PROGRESS:

The January issue of METAL PROGRESS contains my article concerning "Minor Constituents in Copper-Lead Alloys" and on page 47 appears a diagram showing how the electrical conductivity of copper is influenced by very small amounts of a second alloying element.

I am indebted to L. L. Wyman for calling to my attention that all of the alloys shown in his chart were very carefully analyzed *on the finished material* by Mr. Skowronski, from whose data the chart had been prepared, so that only the effects of the materials actually present in the copper were attributed to the change in conductivity of the resulting alloy.

Accustomed to distinguish between "added metal" and "residual metal," the words "added metal" on the published chart misled me to the belief expressed on page 46, right-hand column, second paragraph. In justice to the very excellent work done by Mr. Skowronski, I withdraw the above-mentioned paragraph.

HANS OSBORG
Metallurgical Consultant

Embrittlement of Steels at High Steam Temperatures

CHICAGO

To the Editor of METAL PROGRESS:

An interesting special letter from J. H. G. Monypenny recently made its appearance in your columns (July 1937) directing attention to the important problem of the embrittlement of steels at high steam temperatures. This letter discussed various experiences having to do with the loss of toughness in British-made alloy steels used for studs and bolts in steam plants at temperatures of 800 to 900° F. It was pointed out that the notch toughness of nickel-chromium steels showed considerable decrease when exposed many months at the service temperature and it was suggested that perhaps these steels are for this reason unreliable for high steam temperature service. This former letter, by virtue of its authoritative source and attention directed to it in metallurgical circles through reprinting, may arouse certain fears which the writer of the present communication believes have no foundation.

That the metallurgical facts with regard to embrittlement be true is of course not to be questioned. A loss of notch toughness is generally substantiated by steam exposure investigations upon American-made studs and bolts. However, the significance of all these facts regarding loss of notch impact values from the engineering point of view, as regards studs and bolts, is to be judged rather from years of actual operating experience involving the steels in question, than from the results of Charpy or Izod tests alone.

The impression is gained from the British letter, that actual operating difficulty through loss of notch impact strength is regularly encountered in the use of certain alloy steels for studs and bolts in steam power plants, in a suggestion that "breaking" or unbolting a joint made with bolts which have become embrittled is a hazardous operation. Again it is not the purpose to question that brittle nickel-chromium steel bolts have been a source of trouble in steam plants abroad, but to point out that American-made studs of nickel-chromium steel have caused no trouble of the nature implied.

Nickel-chromium steel of the S.A.E. 3140 type was quite generally supplied as a high pressure bolting material during the decade from about 1920 to 1930. Prior to this period steam power plants had used bolts made from bessemer carbon steel, and as steam temperatures and pressures increased, such bolts were not only unsatisfactory because they had not enough strength, but also because they were frequently found to be so brittle, the nuts would crack off and sometimes fly when loaded bolts were subjected to shock. Indeed, it has become the practice to test joints for brittle bolts by periodically striking each nut a sharp hammer blow. When nickel-chromium and other alloy steels came into use, the trouble disappeared and with it also disappeared any apprehension of the dangers of "flying nuts."

Thousands of tons of S.A.E. 3140 nickel-chromium steel studs and bolts have been put into American steam plants, but the writer knows of no case where brittle failure has occurred. In some plants this grade of steel has been in use for at least 15 years at steam temperatures up to 750° F. At intervals of about two years, the joints are either opened or re-tightened, with never a brittle failure. Although these same bolts will show a definite decline in notch toughness when tested in the laboratory, they have not been known to give any trouble in service.

Since about 1930, suppliers of bolts and studs to steam power plants have substituted for S.A.E. 3140 nickel-chromium steels other alloy steels which have higher creep resistance at temperatures beyond 750° F. However, a vast quantity of S.A.E. 3140 is still giving eminently satisfactory and dependable service under the conditions for which it was installed.

It might properly be inferred from this that nickel-chromium steel bolts and studs have not been subjected to high enough temperatures in steam service to have become severely temper embrittled. Its use was curtailed when steam temperatures started to exceed 750° F. and experiments have shown that temper embrittlement proceeds most rapidly and deeply at about 900° F. Although it is true that very little experience with this steel at 900° F. is at hand so far as steam service is involved, much of it was supplied to the oil industry for high temperature work before the more creep resisting steels came into use. Extensive use on heat exchangers, on stills, return bends, and other places where temperatures of 900° F. were encountered, proved it to be tough enough even under these most drastic embrittling conditions.

J. J. KANTER
Research Metallurgist
Crane Co.

Utilitity of Micro-Manipulators to Metallurgical Research

PARIS, FRANCE

To the Editor of METAL PROGRESS:

Progress in microscopic experimentation in biology, notably the study of biological phenomena by micro-cinematography which Dr. Commandon in France has carried to a high degree of perfection, has led to the creation of an entirely new technique and special experimental apparatus.

Cells and microbes can now be pierced, injected or cut by means of micro-instruments made of extremely delicate glass. Among them may be mentioned micro-needles, solid or hollow, of varied shapes; micro-pipettes varying in diameter from 1 to 20μ and accurate to the micron; micro-hooks; micro-scalpels formed from fragments of glass prepared by special technique and used to cut bacteria in sections. Such micro-instruments, as well as metallic micro-electrodes, are fabricated under a special microscope which uses as a source of heat a platinum wire 0.2 to 0.007 mm. in diameter carrying an electrical current.

These instruments must be capable of being moved in any direction by a supple, delicate and accurate mechanism, closely coordinated with the movements of the operator's hands. This was accomplished by M. de Fonbrune's pneumatic micro-manipulator. A drive lever, mobile in all directions around a universal joint (ball and socket, such as on the "stick" used for guiding airplanes), acts on the pistons of two horizontal crystal pumps, the axes of which are rectangular and pass through the center of rotation of the lever. This lever, or manipulator, which can take any position and the further end of which can traverse any curved path around the axis, is itself composed of a third crystal pump, the piston of which can be moved by the spherical headed screw at the end of the manipulator.

The three pneumatic pumps are rotated with the three pneumatic caps of the receiving apparatus by means of rubber tubes; these caps contain thin corrugated metallic membranes actuating the axis of the receiving apparatus, to which any micro-instrument may be adapted, in three dimensions and in either direction. The end of this instrument, thus animated by pneumatic transmission which prevents any vibration or jarring, reproduces every movement of the hand moving the lever of the manipulator, but in a reduced scale proportional to the magnification used on the optical system. This end can thus completely explore a 3-cu.mm. space.

This beautiful instrument may be so regulated that the proportion between the movement of the hand and the apparent displacement of the micro-instrument remains essentially constant, whatever the magnification chosen, and the direction of the movement always remains the same as that of the hand. It follows the movements of the hand so accurately that it is possible for an operator to write his name in letters less than 0.01 mm. high on a surface smaller than a scale from a butterfly wing!

This apparatus has so far been used only in biological research, but it seems to us that it could render very useful service in metallography for determining and marking points in the study of micrographic structure.

Micro-pipettes could be used to attack certain constituents, and then the resources already offered by micro-analysis could profitably be employed to find out the elementary chemical composition of the point under consideration. This procedure could be used to secure valuable information about primary or secondary dendritic segregation. In studying so interesting a problem (in which quantitative results are now lacking, especially in the complex alloys such as steels) not only direct chemical investigation can be used but also the following methods are made possible by the same apparatus:

Investigation of solution potentials by means of a liquid micro-electrode, formed by a micro-pipette, the liquid of which is connected to a reference calomel electrode.

Spectrographic investigation by striking a condensed spark between the surface and a metallic electrode and then putting to profitable use the considerable progress recently made in quantitative spectrographic analysis.

Finally, brittle or non-cohesive constituents, such as the graphite of cast iron, might be studied by means of micro-test pieces.

In short, it appears that this technique of micro-manipulation should be able to render remarkable service in the study of quantitative microscopic metallography.

ALBERT PORTEVIN
Doctor of Engineering, Honoris Causa

[Micro-chemical analysis is already well developed. An interesting account of its application to communication research and engineering is found in Bell Telephone System Technical Publications, Monograph B-957.]

Wear of Steel Rails and Tires

LENINGRAD, U.S.S.R.

To the Editor of METAL PROGRESS:

Study of rail steels has attracted metallurgists in this country for many years, rails being perhaps the most important item of steel consumed by us. Brittleness at low temperatures is especially dangerous in our northern and Siberian lines. In recent years a great deal of attention has also been devoted by investigators in the U.S.S.R. to the wear of metals, mainly in connection with rails and tires.

These problems had already been studied by a Special Committee for Rails, organized as far back as 40 years ago. As a result of its work, the Committee came to the incorrect conclusion that the low elastic limit — as determined by the mirror extensometer — was alone responsible for the rapid wear of rails. In 1927 these investigations were resumed. A set of 120 rails showing varying degrees of wear had been removed from the track and examined as to their mechanical properties, and the results were examined statistically in the author's laboratory.

From this study it is now known that the mechanical characteristics — insofar as they affect the actual wear resistance of rails — must be arranged in the following order of importance: (1) Brinell hardness; (2) tensile strength; (3) yield point; (4) elastic limit. It has thus become apparent that the latter characteristic is the *least* important, rather than the most.

In 1930, about three miles of experimental rails whose mechanical properties were predetermined were put in track and subjected to a careful inspection and constant measurement. The data yielded by this large-scale experiment are now available, and fully confirm the above statements. Brinell testing may now be considered as the best method for evaluating the wearing qualities of new rails.

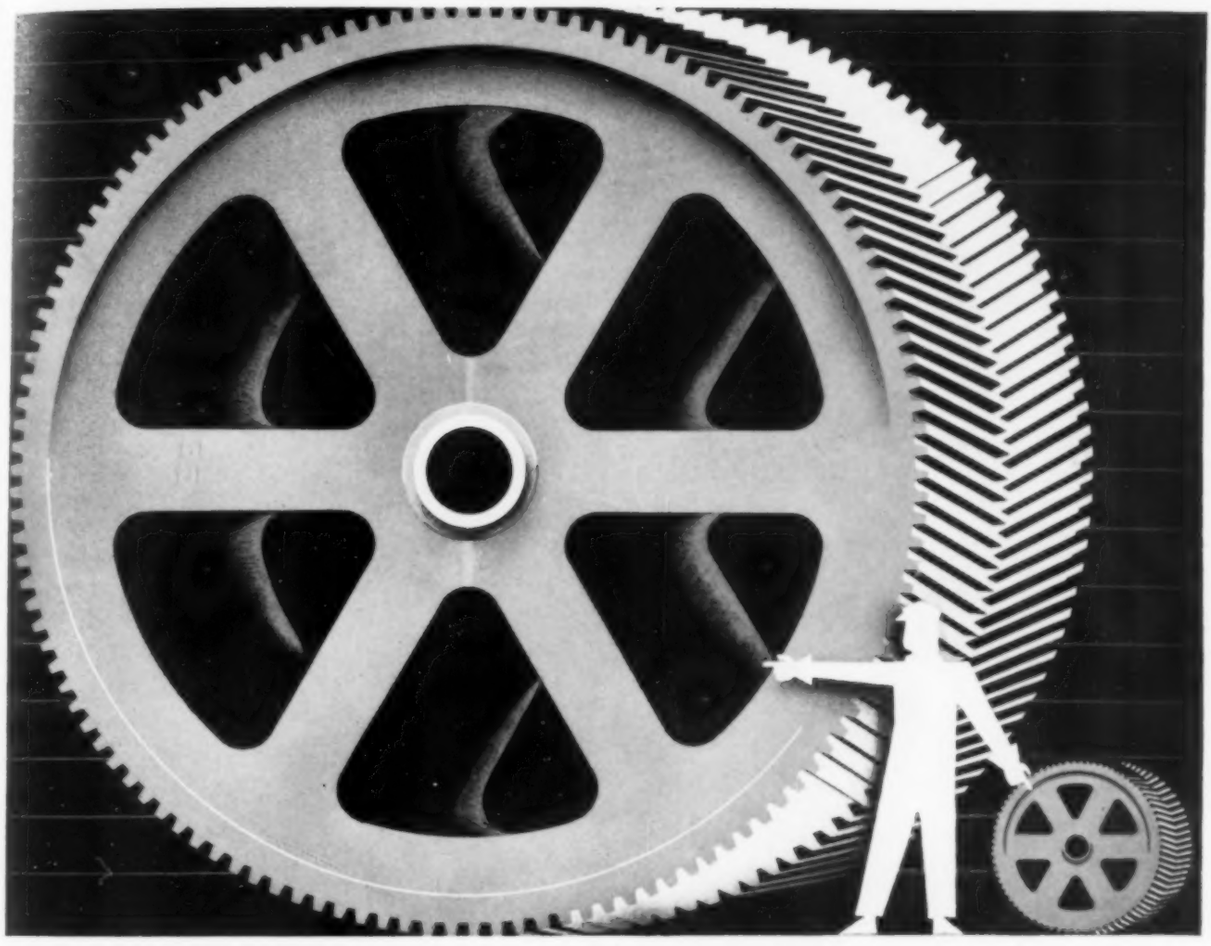
Simultaneously a number of laboratory experiments were carried out. Among them L. Kukanov studied the wear of annealed steel containing 0.40% carbon, using an Amsler wear testing machine. It is possible to obtain on that machine either a pure rolling contact or a rolling with longitudinal or lateral sliding of two specimens under investigation. Kukanov found that in pure rolling contact the wear vanished nearly completely. As soon as sliding, by lateral oscillations of the specimens, was imposed, wear occurred proportional to the sliding amplitude. This wear reveals itself not only in the form of abrasion, but also in the form of plastic deformation of an annealed specimen, which is very remarkable.

The same phenomenon was observed by B. Kislik, who studied the wear of steel tires for rolling stock. His experiments were also carried out on the Amsler machine. One of the two rollers, namely that which represented a tire, was made twice as broad as the other which represented the rail. When rolling was accompanied by sidewise sliding, a slight rut was worn in the broader surface, and a slight ridge of metal pushed up above the original surface at each edge of this rut. It was therefore possible to evaluate the plastic deformation (crushing) by measuring the cross-section of these fillets or ridges. It was shown that during pure rolling, crushing wear is absent under the conditions of these experiments, but in the case of longitudinal sliding, even when the difference between the rollers' velocities is as small as 2%, a considerable wear of both kinds (abrasion and crushing) immediately appears.

Thus the plastic flow of metal is due to sliding friction, while in the case of pure rolling contact it is absent. Abrasive and crushing wears are closely connected. This is probably due to the following two causes: (1) The heat evolution, which decreases the elastic limit, and (2) the appearance of the tangential friction stress, which changes the state of stress toward a greater plasticity in accordance with the maximum shear stress theory.

Kislik also studied the influence on the wear of the following factors, each by itself and in combination: (1) Hardness of steel; (2) its carbon content and (3) its microstructure. It was shown *(a)* that if the carbon content is constant the wear decreases as hardness increases; *(b)* if hardness is constant the wear decreases as the carbon content increases; *(c)* if both hardness and carbon content remain constant, the troosto-sorbitic structure is less resistant to wear than the purely sorbitic one, and the latter is less so than the pearlitic one, particularly if it is coarse grained. Thus the better resistance of the sorbitic structure is a result of its greater hardness, but not of the structure itself. It is noteworthy that sorbitic structure is also tougher at sub-zero temperatures, as noted by Suslov in a letter to METAL PROGRESS, December 1933.

N. DAVIDENKOV
Professor, Institute of Technical Physics



DIFFERENT IN SIZE . . . ALIKE IN STEEL

It's a big jump from a 36-inch gear to one of 16 feet weighing 53,000 pounds. Yet their case histories show that such widely varying sizes can be handled with one steel. In these instances a Manganese-Molybdenum (0.15 to 0.20% Mo) steel was used.

In the large gear simple annealing, normalizing and drawing proved sufficient to produce uniformly good physical properties. The smaller gear permitted oil quenching and drawing to even higher physical properties. And, despite the wide variations in sections, no casting defects or machining difficulties were encountered in either of the two products.

Such is the versatility of Moly cast steels. Our free book, ***"Molybdenum in Steel,"*** tells more about them: and our accumulation of practical field data is available to engineers and production executives toward the solution of any specific iron or steel problem. Climax Molybdenum Co., 500 Fifth Ave., N. Y.

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Personals

Selected to deliver the 12th annual series of Priestly lectures at Pennsylvania State College: **Robert F. Mehl**, director of the metals research laboratory and head of the department of metallurgy, Carnegie Institute of Technology.

Donald E. Babcock has left Republic Steel Corp. to accept a position on an industrial fellowship of the Pittsburgh Steel Co. at Mellon Institute of Industrial Research, Pittsburgh.

Erskine R. Kelly has left Reece Buttonhole Machine Co., Boston, where he was chief tool designer, to operate an experimental and manufacturing shop for the Ramsay Engineering Co. of Birmingham, Ala.



New 48 page illustrated booklet entitled "The Story of Sulphurized Cutting Oils" now available to personnel of metal working plants. Please write to 2727 South Troy Street, Chicago, for your free copy using company letterhead and stating capacity.

Roy H. Smith, executive vice-president of Lamson & Sessions Co., has been elected president to succeed **George S. Case, Sr.**, made board chairman.

Appointed vice-president of operations for Salem Engineering Co.: **J. W. Wagoner**, formerly general manager.

Frederick D. Foote and **Beram D. Saklatwalla** have announced the formation of Alloys Development Corp. of New York as successor to U. S. Rustless Steel and Iron Corp.

Appointed assistant professor of mechanical engineering at University of California: **John Emil Dorn**, formerly research associate at Battelle Memorial Institute, Columbus, Ohio.

Adolph O. Schaefer has been promoted to chief engineer of tests, Midvale Co., Philadelphia.

Walter H. Bruckner has been appointed research associate in the department of mining and metallurgical engineering in the Engineering Experiment Station of University of Illinois.

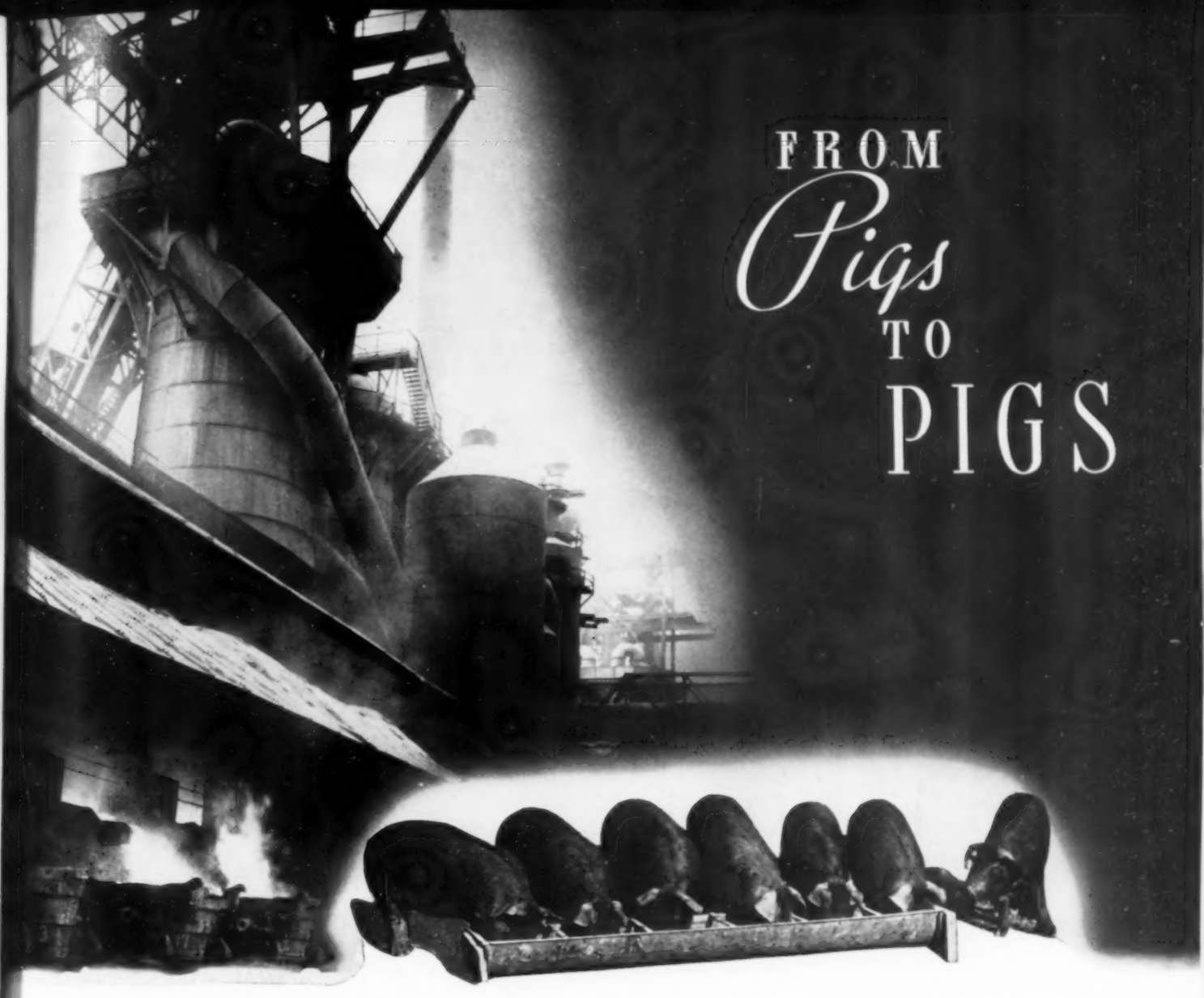
Arklay S. Richards has severed connections with Brown Instrument Co. to form his own company as manufacturer's representative for thermocouples and alloy protecting tubes.

Associated with Surface Combustion Corp., Toledo, Ohio, as consulting metallurgist: **J. A. Comstock**, formerly metallurgist with Illinois Tool Works.

Returned to the employ of R. B. Pond, Inc., highway contractors: **R. B. Pond, Jr.**, formerly with American Rolling Mill Co.

T. N. Hannant is now with Western Electric, Kearny, N. J., as physical measurements and observational standards engineer.

Harold N. Ewertz, formerly of Austin Hastings Co., Boston, is now connected with Arcos Corp., Philadelphia.



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★"Modern" applies today to farms as well as cities--and *steel* has made this true. A sizeable percentage of the "pigs" (masses of metal cast in a mold) from all blast furnaces find their way to the farms in the form of steel---in plows and in modern equipment which increases production; granaries that protect the harvest; pipe, pumps and troughs by which animals are fed and watered.

On an average farm are hundreds of uses for steel. Look around your home--whether farm or city--and note how much you, too, depend on steel --hinges, stoves, cooking utensils, refrigerator, plumbing, heating and countless other uses.

Not, of course, just any steel. There are actually thousands of kinds of steel, and we have spent years and millions of dollars to equip ourselves to work with you, to find which will exactly meet your needs. No matter how small the order may be every Youngstown resource for quality is employed in its production.

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Manufacturers of Carbon and Alloy Steels

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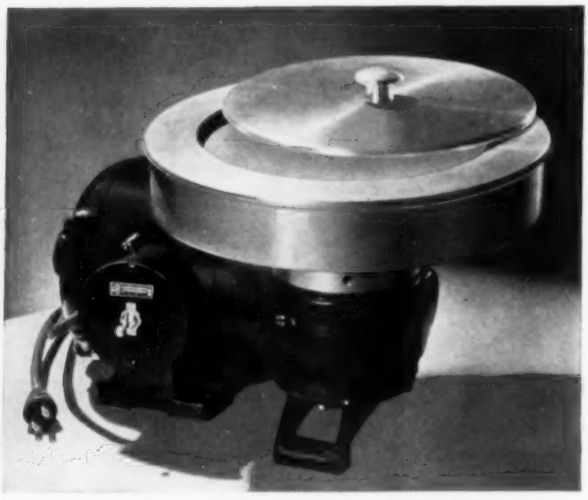
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Bimetallic Compounds

(Continued from page 479)

of chemistry had been built up. It was therefore not surprising that the controversy with Berthollet ended in a complete victory for the Daltonian view. The behavior of such solid phases as the beta phase of the copper-zinc system, with its indication of a compound CuZn, seemed to contradict the accepted view, and it was even proposed to distinguish these apparently variable compounds as "Berthollides," in contrast with the normal "Daltonides."

There was, however, evidence to show that even within these "Berthollide" phases the simple atomic ratio had some significance. When a metal which is a good conductor of electricity takes another element into solid solution, the conductivity is rapidly lowered by even small additions. The typical intermetallic compound was found to have, in many instances, a remarkably high conductivity, which was lowered by the addition of either of its components, so that the conductivity-composition curve showed a sharp cusp at a simple atomic ratio, such as AgMg or CuZn. Similar cusps were found in the curves illustrating the variation of other properties with composition. This seemed to reconcile the idea of the intermetallic compound once more with the facts, but many systems behaved anomalously.

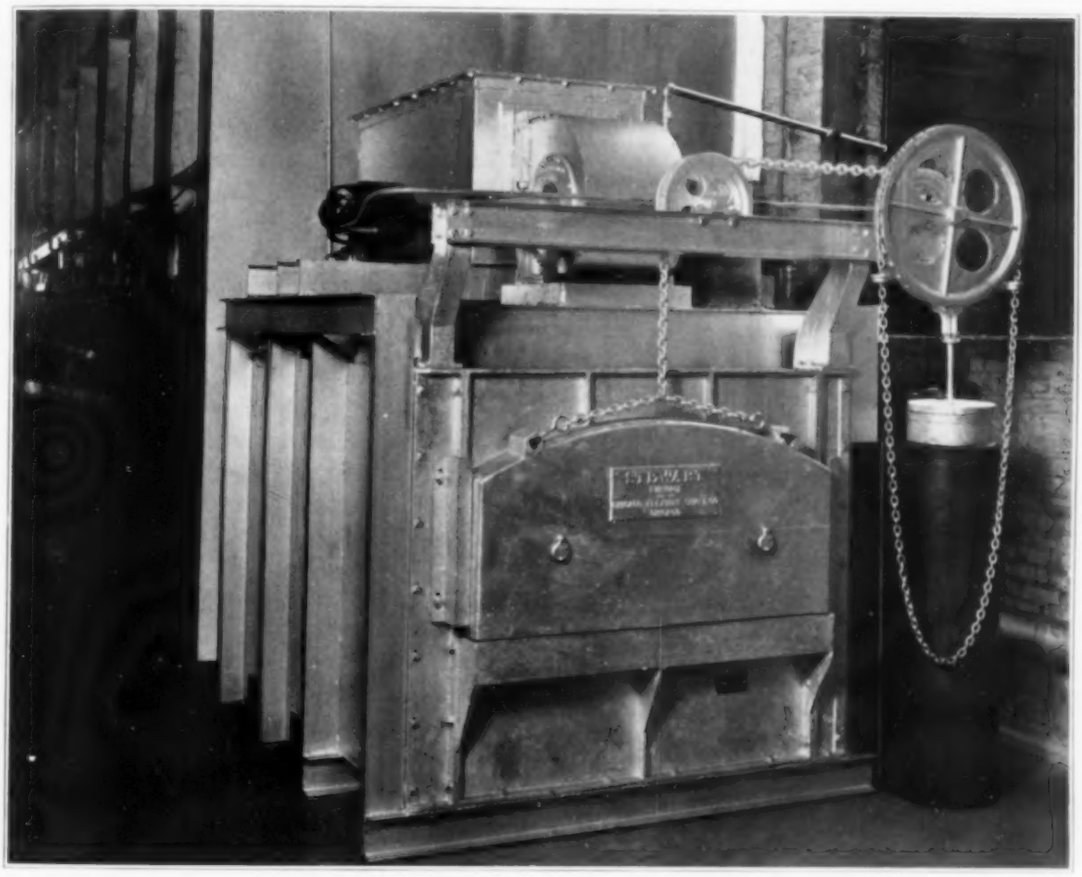
X-ray methods brought new light. It was discovered how the two kinds of atoms were distributed on the lattice, and how the greater regularity corresponding with a simple atomic ratio led to a higher conductivity. Hume-Rothery attached importance to the ratio of valency electrons to atoms in a phase, and thus introduced a new kind of valency, strangely different from the original but yet intelligible. Incidentally, the X-ray observations made it necessary to alter some of the accepted formulas. Cu_2Zn_3 became Cu_5Zn_8, Cu_4Sn became $Cu_{31}Sn_8$, and so on, apparently more complex, but actually fitting better into a definite scheme. It seemed doubtful, however, whether the conception of an intermetallic compound, in the chemical sense, had much further value.

Next came the study of the "order-disorder" changes in solid solutions by W. L. Bragg (*Proceedings* of the Royal Society, 1935).

(Continued on page 522)

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Left: Machining a huge NICHROME casting in the D-H machine shop.

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DRIVER-HARRIS COMPANY
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NICHROME

Bimetallic Compounds

(Continued from page 514)

This concerns the rate at which atoms can change places in a given phase and the temperature of "ordering." In some instances, as in the beta phase of the copper-zinc system, the change to the ordered state takes place so rapidly that no quenching succeeds in preserving the disordered condition. In the alloys of gold and silver no ordering can set in at a temperature at which the atoms have appreciable mobility, so that they remain permanently disordered. In such systems as copper-gold and iron-aluminum the velocities and temperatures are such that the conditions can be controlled and the transformations studied.

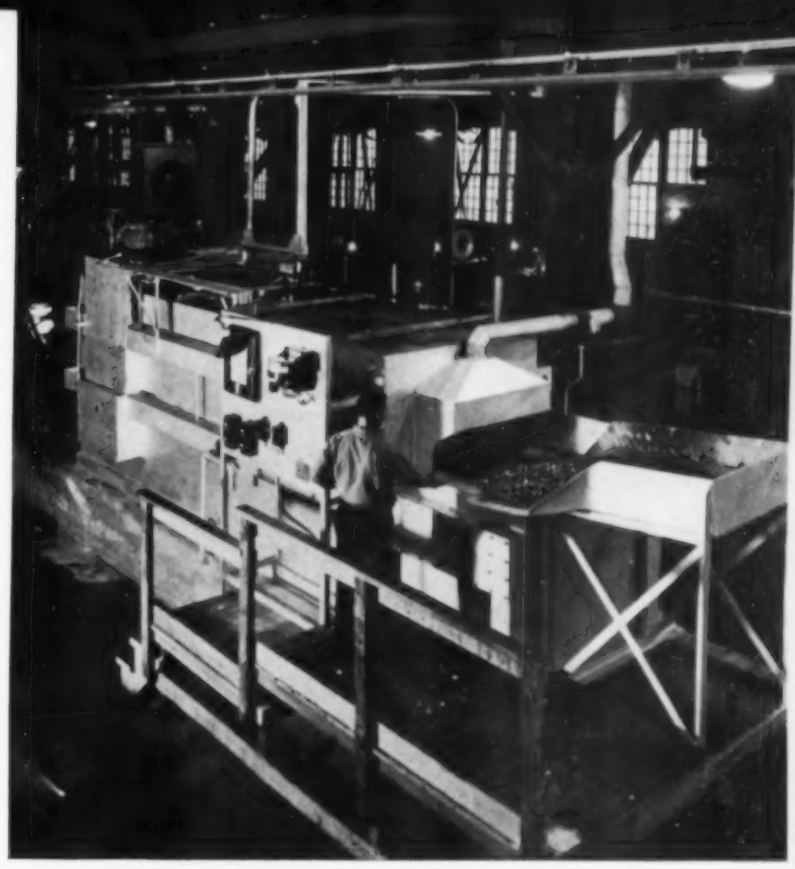
Again, there are some phases which are completely ordered as they crystallize from the melt, and never become disordered. They are most often marked by a strong maximum on the freezing point curve, and that they persist in the ordered condition *even in the molten state* is shown by the fact that on a conductivity-composition curve of the liquid alloys they correspond with an upward-directed cusp, such as is found in solid solutions. It seems right to speak of these phases as true intermetallic compounds. $NaHg_2$ is a typical example. That the atoms in phases of this kind are held together differently from those of most other alloys is shown by their high heat of formation, suggesting an ionic linking as in salts. Here, then, we have strong evidence that some alloys have an ionic character.

I mention the subject here because it shows that the well-established laws of chemical combination, which seemed to have lost their meaning in the field of alloy systems, are found once more when the properties of the metallic state are more searchingly studied. I am confident that in the immediate future, while the recent great additions to our knowledge of solids are being completed, chemical considerations will be found to play an important part. The doctrines of valency and of structure, which served so unfailingly in building up the great edifice of organic chemistry, often proved less certain guides in the inorganic field, but now in the light of new discoveries concerning crystal structure, those doctrines reappear, and are still of service.

New Development

HARDENS HIGH CARBON OR ALLOY STEEL WITHOUT "DECARB"

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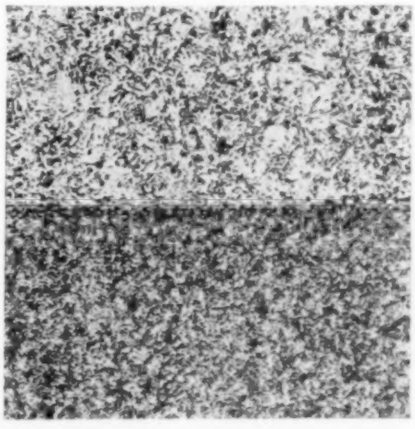
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You too, can get the same results. The type of results that can be expected are well illustrated by these unretouched photomicrographs of a section through a joint of two samples that had been soaked for 30 minutes at 1510°F. The uniformity of the grain structure and the surface condition between the two samples show that this hardening is really without "decarb."



Unretouched Photomicrograph. Cross section of two specimens clamped together. Top—Carbon Molybdenum Steel C-0.50; Si-1.0; MO-0.50. Bottom—Carbon Chrome Steel C-0.95; Cr-1.20.

Consult Westinghouse for the latest and most efficient developments in hardening or annealing metals. Simply call your nearest Westinghouse office, or write Dept. 7-N, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

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Who's Who in This Issue

THE BEGINNINGS of metallography in America may be said to date from the day in 1891 when a curly-haired young man of 28, with a mining and metallurgy degree from M.I.T. to his credit and two years as chemist for Pennsylvania Steel Co., was given a poorly lighted laboratory containing a microscope, and told to go to it. He was **Albert Sauveur,** and the laboratory was in the plant of Illinois Steel Co. in South Chicago. "Five happy years were spent in this way, nearly each day made brighter by what seemed to me a little advance in a research in which I was now deeply interested, which was to continue 45 years, and which, God willing, may go on a few more years," Dr. Sauveur writes in his reminiscences. But then came what he terms a hurricane in the form of a new president and the metallurgical laboratory was washed away. Sauveur opened his own testing laboratory and for seven years published the now-famous **Metallographist.** In 1899 he joined Harvard University for a career of teaching and research which has won him the title of "Dean of American Metallurgists." His character and personality are well typified by the whimsical but earnest contribution on page 473.

Few of us have the opportunity of helping to start a business the year we step out of high school. **L. A. (Roy) Lindberg,** together with his father, A. N. (Old Man) Lindberg, launched the Lindberg Steel Treating Co. in 1922, and after a year of practical heat treating experience during which time the business enjoyed substantial growth, Young Man Lindberg had enough money to enter the University of Illinois. Vacations and practically all spare time he devoted to the heat treating company, and he graduated in 1927 with a B.S. in Metallurgy. Today he is vice-president and general manager of the steel treating company and secretary of the Lindberg Engineering Co., the manufacturing subsidiary.

When the research laboratory of the United States Steel Corp. was opened in Kearny, N. J., ten years ago, **J. B. Austin** was one of the first to join the staff. He has been there ever since and divides his time about equally between metals and refractories. The latter subject is covered in his report of the Ceramic meeting on page 494. Mr. Austin is a chemical engineering graduate from Lehigh University (1925) and has a Ph.D. from Yale University, obtained in 1928.

A.S.M. Trustee **Ralph L. Wilson** is a reliable contributor to its technical sessions and held a prominent place in the Western Metal Congress program with two papers on his specialty — metallurgy of steel for high temperature applications. One of them on "High Temperature Strength of Steels" is published on page 499, while the second on "Tubing for Oil Heaters" was abstracted in last month's issue. Mr. Wilson is a 1921 graduate from Lehigh University. He served on the metallurgical staff of the United Alloy Steel Corp. from 1921 to 1926, and Central Alloy Steel Corp. from 1926 to 1928. From then until late last year he was metallurgical engineer for Timken Steel & Tube Co., and is now the same for Climax Molybdenum Co.

Albert Sauveur



L. A. Lindberg



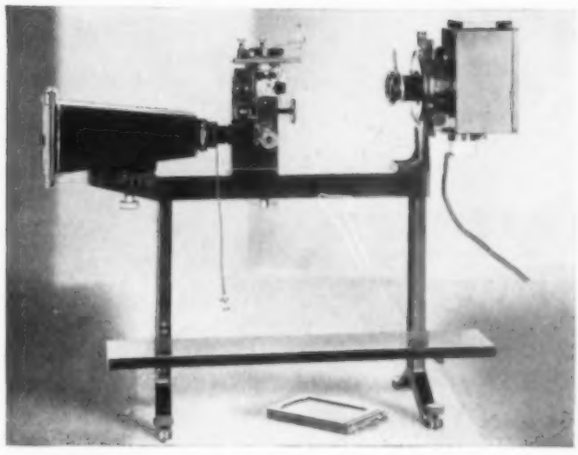
Ralph L. Wilson



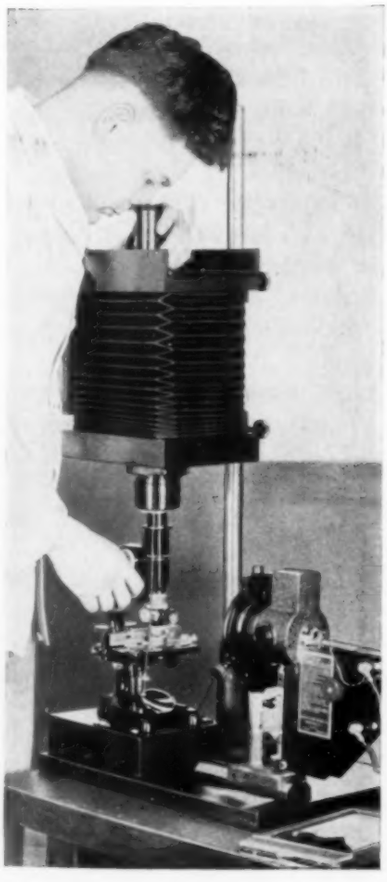
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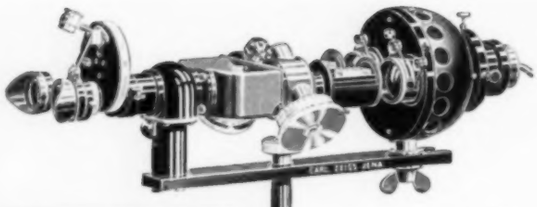
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	Flexibility is a feature of the FSM with the J Camera. Adaptable to any type of Metallography, Micro Photography. Capable of a variety of work. (Shown on left.)	For speed and convenience in making routine Photo-micrographs use SI equipment. Permanently aligned, always ready to use, it fills a need in any metallographic laboratory.
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General Purpose	A flexible—all-purpose outfit.	For all routine work within magnification range.
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Mn:	about ± 0.015%	with content up to 2%
Cr:	about ± 0.025%	with content up to 2%
Cu:	about ± 0.01%	with content up to 1%
Si:	about ± 5%	of total content present over 0.5%
	about ± 10%	" " " " under 0.5%

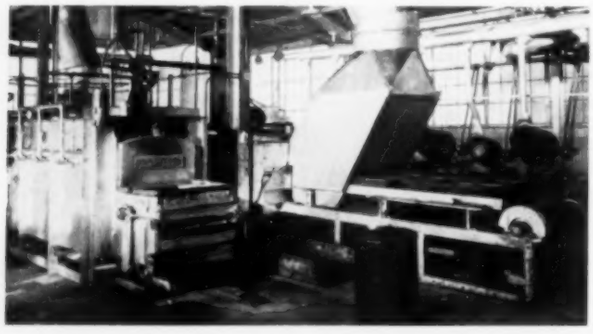
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DETROIT, MICH.

To the Editor of METAL PROGRESS:

Spark plugs for internal combustion engines must withstand some of the most severe operating conditions known. Early researches into the proper metals for the points were later commercialized in the form of heat and corrosion resistant alloys. It is not surprising, therefore, that studies of the porcelains should result in a useful byproduct in the form of a "super-refractory" of the sillimanite family.

Sillimanite is the name of a mineral discovered in 1792. Other minerals have the same chemical composition, $Al_2O_3 \cdot SiO_2$ in the pure form, but may be distinguished from each other by crystal system or habit or optical properties. The most important of these are cyanite and andalusite; other forms are chiastolite, fibrolite, bamlite, zenolite and worthite. Two more complex aluminum silicates of interest to refractory makers also exist as natural minerals, namely dumortierite and topaz. Properties of all these are listed in the data sheet in METAL PROGRESS last October, page 383.

Up to 1920 these minerals of known refractory properties were rare — or at least unavailable in tonnage. Consequently ceramists at the National Bureau of Standards, working on spark plugs, attempted in 1917 to prepare artificial sillimanite by firing a proper mixture of clay and alumina. The resulting calcine was free of sudden volume changes at high temperatures, and when substituted for potter's flint in the body of porcelain increased the mechanical strength two to four times, and vastly improved its resistance to heat shock. About seven years later, a study of the SiO_2-Al_2O_3 equilibrium diagram by Bowen and Greig showed that these artificial melts were not sillimanite even though the two oxides were present in equal molecular proportions, but that any fused mixture on slow cooling would transform into a compound $3Al_2O_3 \cdot 2SiO_2$ and excess constituent (SiO_2 or Al_2O_3 as the case may be). This compound they called mullite. Its physical and optical properties are similar *(Cont. on page 530)*

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Correspondence

(Cont. from page 528) to the natural mineral sillimanite, and previous investigators had failed to recognize any differences.

Sillimanite refractories, sintered or highly calcined, therefore tend to be mullite plus a little silica glass (cristobalite). At long stays at high temperatures the mullite crystals grow and pools of glass accumulate, an action prevented by a small amount of fine corundum (Al_2O_3) and andalusite ($Al_2O_3 \cdot SiO_2$), which combine with excess silica.

Exploration has also discovered satisfactory deposits of the necessary minerals. Andalusite is produced from a mine in the Inyo range in California, cyanite from a deposit near Calcutta, India, as well as in some of our own Southern states, and dumortierite in the Humboldt Mountains in Nevada. Since 1922 the Champion Co. has made several hundred million spark plug cores in which andalusite has been the major constituent. They are fired at 2650° F., (at least 300° F. higher than ordinary ceramic products) and for this purpose use is made of andalusite refractories for car tops operating in tunnel kilns, as well as for kiln linings, burner parts, and saggers. Resistance to thermal shock is shown by kiln crowns, exposed to temperatures from 3000 to 3200° F. on each heat, often removed when the kiln is hot, which show no signs of spalling after 100 heats. Laboratory work confirms experience and shows superior strength and stiffness at 1500° C. (2725° F.); the andalusite refractory is also higher in A.S.T.M. standard load test and tests on loaded sag bars. Some data follow:

Density, fired at cone 16	0.0861 lb. per cu.in.
Pyrometric cone equivalent	38 to 39
Per cent absorption	11.59
Coefficient of expansion, per °C.	
Range 25 to 200° C.	4.06×10^{-6}
Range 25 to 500° C.	4.99×10^{-6}
Range 25 to 1000° C.	5.91×10^{-6}

While the Champion Co. has made no attempt to market these brick in a large way, they have been manufactured for special purposes where severe service warrants their cost. These are now available from several makers and are gaining a definite place in industry.

FRANK H. RIDDLE
Director of Research, Ceramic Division
Champion Spark Plug Co.

Correspondence

Metals for Osseous Joinery

WEST POINT, N.Y.

To the Editor of METAL PROGRESS:

Mr. Weiss' letter, "Surgeons Want an Alloy for Broken Bones," and your accompanying note in the January issue require further comment. Bone plates and screws are used only in cases where it is not possible to join broken bones without resort to surgery. In such cases they are valuable for holding the broken ends in close proximity and in proper alignment until nature repairs the break. Then, in more than 90 cases out of 100, the bone plate is removed because it is considered unwise to leave foreign materials in the body, regardless of their composition.

Isolated cases in which the plate and screws were of different composition have led to rapid deterioration by electrolysis, as should be expected. In the majority of cases, however, the plate and screws are found to be in excellent condition when they are removed, after 9 or 10 months in the body.

The standard material for bone plates and screws, as indicated in Bureau of Standards circular CS 37-31, is S.A.E. 6150 (chromium-vanadium steel). But surgeons, like all of us, are constantly searching for better materials. Stainless steel (of the low carbon, 18% chromium, 8% nickel analysis) has been used succesfully, and "vitallium" may prove to be satisfactory.

That these surgeons conducted experiments on problems the answers to which we knew, and that they wasted time on materials a metallurgist would have warned them against, is indeed to be regretted. While the obvious is closer cooperation, your suggestion that, "it would be interesting to know if it (hastelloy) would not also be suitable for osseous joinery (if it could be determined in the regular course of hospital operations without further requisitions on the dog pound)" implies that their next experiments be conducted on human beings rather than dogs. Those San Antonio surgeons may feel about that the same way we feel about their distrust of rustless steels because of the high percentage of iron in them.

D. J. MARTIN
Metallurgical Engineer



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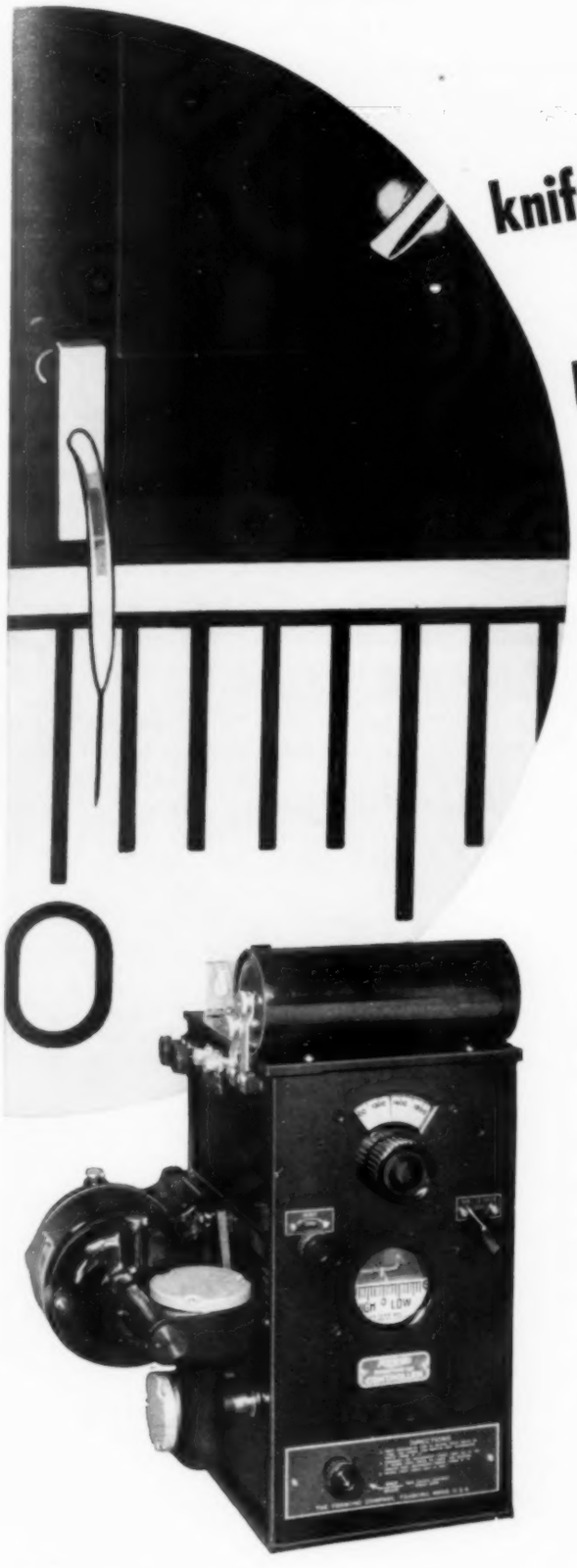
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The Cost of Steel

(Continued from page 505)

Let us now discuss a few points somewhat more specifically, as a means of illustrating the present trends.

The first step is the mining of the raw materials — the ore, the limestone, the coal — and their transportation to the furnace. On the average these raw materials have to be hauled a distance of more than 500 miles at a cost which is of the order of $5 per ton of steel produced. The cost of the raw materials delivered at the plant is likely to increase rather than to decrease, as we shall be forced to use ores carrying a smaller percentage of iron.

The next step is the reduction in the blast furnace. As now carried out, this step is much more efficient in the utilization of raw materials than is commonly believed; indeed it ranks with the most efficient industrial processes. Further improvement is, of course, possible, but this will be in the direction of fitter quality and better uniformity of product day after day rather than in improved utilization of ore or coke.

There have been repeated attempts, on which a great deal of effort and money has been spent, to carry out this step at a lower temperature so as to produce a solid iron, for which (as a material for conversion into steel) advantages have been repeatedly claimed though never demonstrated. But a careful analysis of this matter shows rather conclusively that this procedure cannot possibly compete with the blast furnace as an efficient means of producing iron for steel making on a large scale; if economically feasible at all, it could only be on a small scale and under quite special circumstances not met with in or near the steel consuming region of this country.

The next major step is to convert the crude iron into steel by refining it, either in the bessemer converter or the openhearth furnace.

None of the steel-making steps compares with the blast furnace with respect to efficiency in utilization of fuel. In the openhearth furnace there has recently been marked progress in this direction, the average thermal energy per ton of steel produced being only about one-half of what was used a decade ago. This has been effected by better combustion through regulation of draft and fuel supply, to saving of heat through insulation and tightening of the furnace structure, and to improved control of the effective temperature within the furnace. . . .

A steel article is the end result of a long series of operations, from the selection and transport of

(Continued on page 542)

HOW RESEARCH HELPS CUT YOUR FUEL BILL



1 Less than thirty years ago, there was no satisfactory insulating material for high-temperature industrial equipment. No known substance combined low conductivity and the necessary heat resistance. But in 1912, when Sil-O-Cel Brick and other diatomaceous silica insulations appeared, heat waste ceased to be a necessary evil. Later developments of the J-M Insulation Research Laboratory, notably Superex Blocks, made it possible for steel mills and metal-working plants to bring heat even more completely under control. Today, there is a Johns-Manville Insulation for every type of heated or refrigerated industrial equipment.



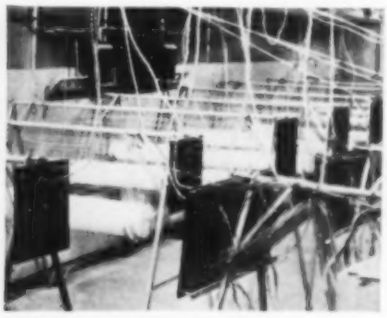
2 3200° F. is the temperature of this Ajax Northrup electric furnace, used to test high-temperature insulations in the J-M Laboratories. Such temperatures, far above the ordinary range of industrial processes, make it possible to check in advance the exact behavior of J-M insulations under severe conditions.



3 Electrical current, accurately measured, is the source of heat for all thermal-conductivity tests in the J-M Laboratory. Power input to any heater in the laboratory may be measured at this switchboard to within ½ of 1%.



4 Measuring the efficiency of high-temperature insulating materials is difficult, for ordinary testing equipment breaks down under high heat. But this J-M testing unit gives accurate conductivity data up to 2600° F.



5 Pipe Insulation is tested for thermal conductivity on these electrically heated pipe sections. The room is kept at constant temperature under thermostatic control. Accuracy is safeguarded at every point.



6 "Jack" Switchboard to which is connected the thermocouples used in the various testing units. Here, with the aid of a single precision potentiometer, temperatures are measured to within ⅕ of 1° F. Temperatures may be measured at approximately 800 different points.

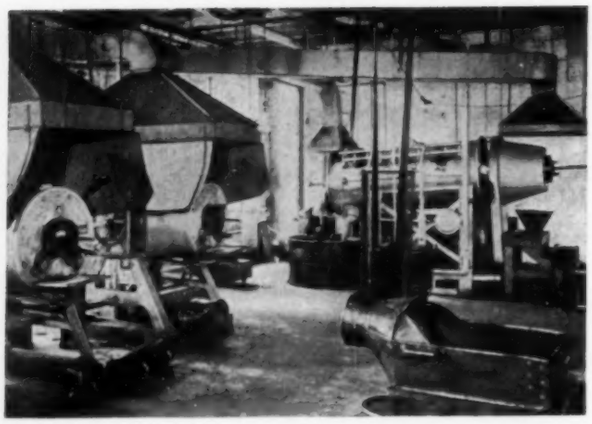
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The story of this laboratory and of what it is doing to solve tomorrow's insulation problems is told in the handbook, "Heat." This interesting book also gives useful information on the full line of J-M Insulations for all industrial purposes. If heat conservation is one of your problems, you'll find this book most helpful. For your copy, write Johns-Manville, 22 East 40th Street, New York, N. Y.

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The Cost of Steel

(Continued from page 538)

the raw materials — ore, coal, limestone — through the making of iron to the manufacture of the steel and its subsequent fashioning and finishing; and the steel may not fit its purpose if there has been inadequate care in any one of these many steps. Withal, highly finished steel is now sold for about three cents (or less) a pound, of which the cost of transportation is an appreciable fraction.

It may be noted that some of these steps seem to constitute a somewhat round-about way of reaching the goal. For instance, we make iron in one furnace and convert it to steel in another, whereas the primitive smith made it in a single step. Or again, we cast thick ingots weighing tons as a starting point in making thin sheet or strip, whereas it would seem possible to cast the steel in some form which would require less rolling to yield the finished sheet. The answer is that no one yet has been able, in spite of repeated trials, and the efforts of many men, to make in these seemingly more direct ways products of equal quality as cheaply as they are made by the methods now in common use. These separate steps are akin to a division of labor, in which each can by specialization be carried out better than has yet proved feasible when the steps are combined into a single operation. Some minor steps have been simplified or eliminated, others will be modified; but there is no indication of a major change in the general methods of large-scale steel production in the near future.

The technical problems now facing the steel industry are somewhat different from what they were a generation ago. Then they related mainly to increased production of a few kinds of steel; now the object is improved fitness of the steel at no greater over-all cost to the public. In general, there has been a gradual decrease in the number of man-hours required per ton of any given product, yet the total number of men employed has increased. This, though due partly to increased total production, is to be ascribed mainly to the greater proportion of more highly finished, lighter products which require more work and more skilled attention per ton of product. We can in general expect little further reduction in man-hours per ton of finished products — there may even be an increase if reckoned on this basis. We can, however, look forward with confidence to fitter quality and thereby to better economy in use; and these steels of the future, while they may cost somewhat more per unit of weight, will undoubtedly cost less per unit of serviceability.